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High Pressure Hydraulic Distribution System

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This program evaluated 8000 psi plumbing hardware using 3AL-2.5V titanium as the basic tubing material for high-temperature, high-performance plumbing systems. This program also evaluated and selected from a field of existing types the most promising permanent joint and detachable tube fittings, hoses, swivels and quick disconnects for use in an advanced aircraft hydraulic system. The feasibility of the resulting system was demonstrated by installing selected plumbing hardware and tuning in a hydraulic plumbing demonstrator and subjecting the plumbing system to 125 hour endurance test, which simulated 2500 hours of aircraft operation.

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FOREWORD

This report was prepared by Rockwell International, North American Aircraft (NAA) for the United States Air Force under Contract F33615-86-C-2634. The work was administered under the direction of the Aero Propulsion and Power Directorate, Wright Laboratory, Air Force Systems Command, Wright-Patterson AFB, Ohio. Air Force Program Managers were in turn, Kristen Schario and Edward Durkin (WL/POOS-1). Mr. J.L. Schmidt was the Rockwell Program Manager, and Mr. D.E. Blanding was the Principal Investigator.

This report documents the entire program effort, which was performed from 23 September 1986 to 30 September 1990.

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1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

Next generation high performance military aircraft will push the state of the art in structures, propulsion, guidance and control, weapons and other systems. Aerodynamic and control advancements permit aircraft to be designed for negative stability in supersonic flight and to have increased maneuverability. These features dictate an increase in hydraulic power and a decrease in the allocations for space and weight in a more severe dynamic environment. Revised system design criteria and verification test methods are required to keep pace with the need to improve hydraulic system reliability/maintainability through a reduction in distribution system failure rates while operating in a more severe environment. The design technology for 8,000 psi systems must be based upon verified design criteria and valid test data to provide significant improvement over the 3000/4000/5000 psi state-of-the-art systems.

1.1.1 BACKGROUND

Airframe integration test methods and procedures for validation tests have been slow and expensive. This is because the complex simulated impulse shape which represents a damped or ringing effect cannot be duplicated at a high rate. Rockwell has initiated the use of sine wave impulse testing in its Hydro-Mechanical Laboratory. This impulse shape can be induced a· a significant faster rate and has proven to be a more reliable, reproducible, cost effective test method.

It is also becoming increasingly apparent that the recognized mothod of damped wave impulse pressure testing (MIL-F-18280) produces limited results. This method establishes a pass/fail criteria to determine component performance. Test-to-pass criteria does not establish a performance rating between potential component designs; it does not determine the remaining design margin available, e.g., the component's tolerance for a slightly more severe dynamic environment. A current method of producing more tangible test data addressing these deficiencies is the test to failure criteria utilizing stress versus cycles to failure S-N curves.

S-N curve testing makes it possible to meet the functional requirements of the plumbing hardware in that it yields data (in the form of a pass/fail S-N "design to" curve) at both high and low and stresses in between. For flexure tests, this data can be compiled at any "R" factor (ratio of the minimum to the maximum bending stress) ranging from -1 to +1, while for impulse tests the data can be compiled at any positive "R" factor. In either event, once the basic minimum S-N characteristic curve is known,

the data can be converted analytically to other stress conditions with a relatively high degree of accuracy. This type of data, together with Goodman Diagrams and Computerized structural analytical programs, provides the necessary design guidelines to include the aircraft dynamic environment in the overall design of the distribution system.

1.1.2 PROGRAM OBJECTIVE

The major objective of this program was the development of design criteria for hydraulic distribution system components with a high probability of producing a leakproof system over the life of advanced aircraft.

The program developed the design criteria through: 1) review of the design features of current system components, the types of failures experienced in operational aircraft and the assembly, manufacturing and installation problems that exist with current fittings; 2) definition of the expected installation environment for advanced fighter aircraft; and 3) the experience gained from 20 years' development of 8,000 psi hydraulic systems. The criteria was used to design components, and screening tests were conducted to determine the best component for the program. In conjunction with the establishment of the design criteria, an impulse test was conducted to compare the results of the current conventional damped wave method with an impulse fatigue method using sine-wave shaped impulses.

Once the screening tests and the impulse comparison tests were completed, a distribution system demonstrator was designed, constructed, and a series of endurance tests was conducted. The demonstrator was designed to subject typical hydraulic system installation components to an environment which simulates advanced aircraft. The tests were structured to verify the demonstrator using the developed design criteria for hydraulic distribution system components

1.2 PROGRAM SUMMARY

Technical activity for this program is divided into eight tasks covering 29 months. Total program effort covers 34 months which includes completion of a final report.

The eight technical tasks are delineated as follows:

Task 1 - Establish Design Criteria

This task established specific design criteria for all components of the distribution system.

Task 2 - Impulse Correlation Test

This test provided comparative data between two impulse test methods to establish (1) whether or not the two methods produce comparative results and (2) whether or not the sine-wave impulse test gives more consistent results. The results of this test established the type of impulse testing to be used for the remainder of the program.

Task 3 - Establish Screening Test Procedures

This task established the test plan for the screening test and incorporated the results of the impulse correlation test.

Task 4 - Conduct Screening Tests

Component screening tests were conducted to ensure consistent and unbiased test results. The most promising designs were identified for subsequent use in the demonstrator.

Task 5 - Design Demonstrator

This task modified the demonstrator design (AF33 (615)-5407 contract) to accept seven line sizes in lieu of five and to accommodate hoses, fittings, swivels, and disconnects.

Task 6 - Fabricate Demonstrator

A demonstrator was fabricated using the detailed design established in Task 5. Instrumentation was located throughout the demonstrator to monitor stresses, temperatures, vibration, and pressures.

Task 7 - Conduct Durability Test With Demonstrator

After a complete system checkout, the endurance test was performed according to the approved test plan. All failures were documented. Replacement hardware was used.

Task 8 - Reliability/Maintainability

Improvements, reliability and maintainability of the final demonstrator design utilized experience gained from the B-1B and other military programs.

1.3 DOCUMENTATION AND SCHEDULE

This final report documents the completion of this program's activities. This final report consists of a comprehensive, detailed account of all technical activity during the test program. It includes conclusions and recommendations for the direction of future effort.

Figure 1 is the program schedule which shows tasks, milestones, and CDRL's.

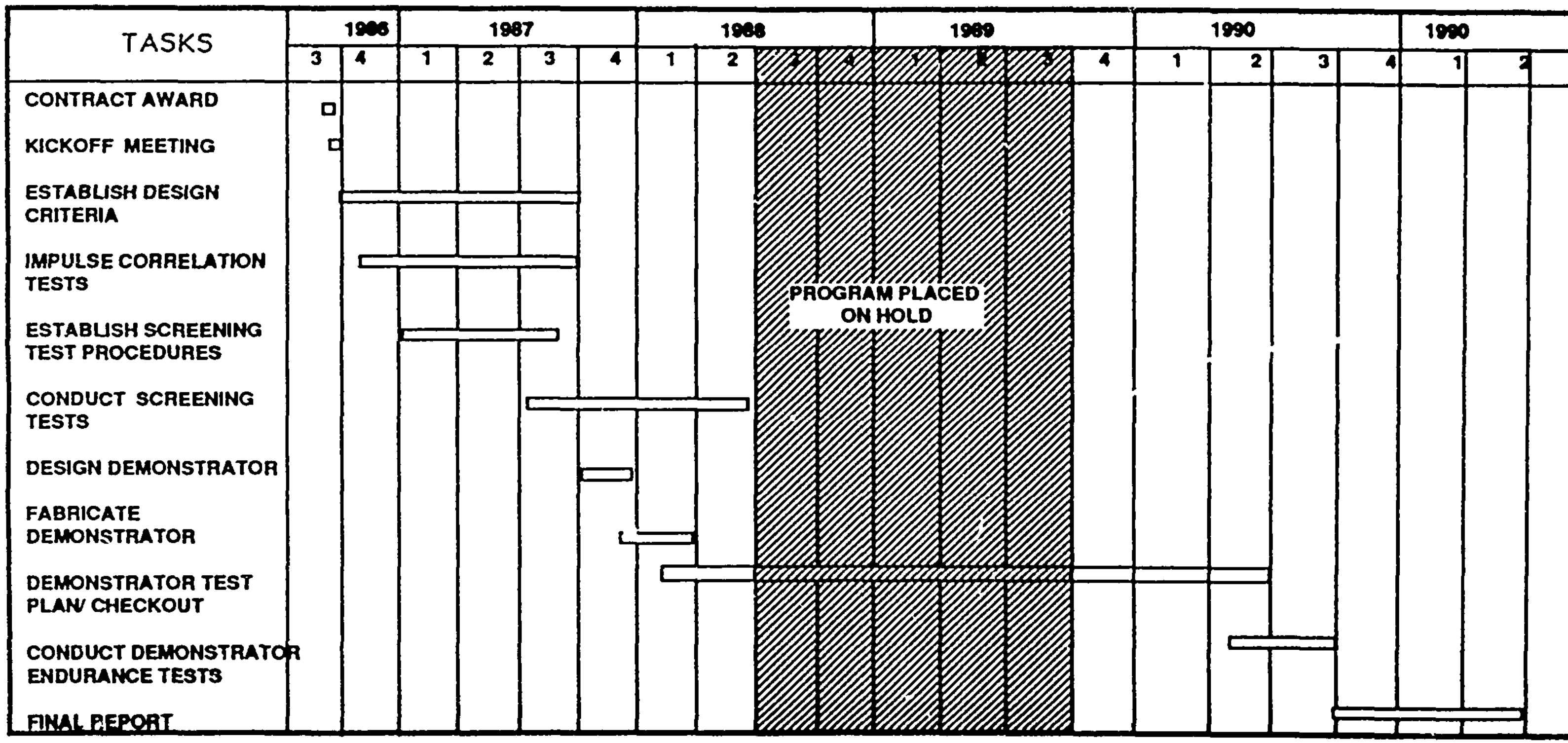


FIGURE 1: PROGRAM SCHEDULE

2.0 DESIGN CRITERIA AND CORRELATION TESTS

2.1 TASK I - ESTABLISH DESIGN CRITERIA

The first consideration of the program was the establishment of component design criteria for the extended aircraft operational environment. General requirements are listed in Table I.

TABLE I
DESIGN CRITERIA

Hydraulic System Pressure	**8000 PSI**
Test Fluid	**MIL-H-83282**
Fluid Temperature Range	**-65°F TO 400°F**
Tubing Material	**Titanium 3AL-2.5V**
Tube Sizes	**3/16 Through 15/16**

2.1.1 PROCUREMENT SPECIFICATIONS

Preliminary procurement specifications were generated for all Distribution system components. These Documents were released to all suppliers participating in the program. The documents listed below are included as Appendix A.

L272C8000 Tubing, 3A -2.5V, Alloy, Seamless, Hydraulic, 8000 psi Aircraft

L273C8003 Fittings, Fluid Connections Aircraft, 8000 psi

L271C8000 Hose Assemblies, Hydraulic, 8000 psi, Aircraft

L278C8001 Joint, Swivel, Hydraulic, 8000 psi, Aircraft

L276C8002 Coupling, Quick Disconnect, Self-sealing, Hydraulic, 8000 psi, Aircraft

2.1.1.1 Tubing Material

The tubing material (titanium 3AL-2.5V) was fabricated in accordance with Rockwell's tubing specification L272C8000 (Appendix A).

All required tubing was received from Haynes International (Cabot Wrought Product Division).

The amount of tubing received was sufficient quantity to support both the screening test and demonstrator phases of the program.

The tubing wall thickness requirements were calculated based on an operating temperature of 400°F and a system pressure of 8,000 psi with a burst factor of 3. At 400°F the temperature reduction factor is 82 percent, thus Ftu (ultimate tensile stress) at 400°F operating temperature is 0.82 X 125,000 = 102,000 psi. The burst pressure, P, is 3 X 8,000 = 24,000 psi. Transforming Lame's equation into a form that permits solving directly for the required wall thickness, t, give the following:

$$t = \frac{D}{2}\left(1 - \frac{Ftu-P}{Ftu+P}\right)$$

Solving for t in terms of the outer diameter D:

$$t = \frac{D}{2}\left(1 - \frac{102{,}000 - 24000}{102{,}000 + 24000}\right)$$

$$= \frac{D}{2}(1-.787)$$

$$= 0.1065\,D$$

Outer Diameter (D), in.	Wall Thickness, in.
3/16	0.020
5/16	0.033
7/16	0.047
9/16	0.060
11/16	0.073
13/16	0.087
15/16	0.100

The tube wall hoop stresses at the 8,000 psi system operating pressure, p, should not exceed FTu (102,000 psi) divided by the burst factor (3.0). Thus the maximum hoop stress on the inner surface should not exceed 102,000/3 - 34,000 psi. Solving for the inner surface stress using Lame's equation in the form

$$S = P \frac{D^2 + d^2}{D^2 - d^2}$$

P = Internal pressure (burst) 24,000 psi
S = Ultimate tensile stress (Ftu)
D = Outside diameter, inch
d = Inside diameter, inch

gives the following schedule of wall stresses at the systems operating pressure, 8,000 psi.

OUTER SIDE DIAMETER	INNER HOOP STRESS, PSI t = 0.1065D
3/16	34,000
5/16	34,000
7/16	33,500
9/16	33,800
11/16	34,000
13/16	33,800
15/16	33.900

The hoop stress on the tube outer surface is approximately 76 percent of the stress on the inner surface. = 0.76 X 34,000 = 26,000 psi.

The mechanical and chemical properties are shown in Tables II and III. All tubing was subjected to a cold working process called autofrettage. During the process, the tubing is subjected to an internal pressure of sufficient magnitude to plastically deform the wall of the tube so that favorable residual-stress patterns are produced (Figure 2). The strength of the tube is reflectively increased which provides many associated benefits such as increased fatigue life, stress relieving, reduced ovality, reduction in stress risers resulting from flaws and manufacturing defects, and more consistent test results with less scatter.

TABLE II
3AL-2.5V TUBING MECHANICAL PROPERTIES

TUBE SIZE (INCH)	WALL THICKNESS (INCH)	YIELD STRENGTH PSI x 1000	ULTIMATE STRENGTH PSI x 1000	ELONGATION %	CSR VALUES	AUTOFRETTAGE PRESSURE ± 2% PSIG
3/16	0.021	115.9	139.5	12	1.110	28,600
5/16	0.034	115.7	138.5	13	0.986	29,000
7/16	0.049	115.8	135.7	15	1.064	29,600
9/16	0.063	113.0	137.0	17	1.022	29,700
11/16	0.076	110.5	133.0	18	1.100	27,800
13/16	0.089	112.3	128.8	10	1.031	27,400
15/16	0.102	108.2	134.2	19	1.740	28,300

TABLE III
CHEMICAL ANALYSIS OF TITANIUM 3AL-2.5V TUBING

	11/16 x .073	13/16 x .087	7/16 x .047	9/16 x .060	15/16 x .100	3/16 x .020	5/16 x .033
AL	3.41	3.49	3.20	3.41	3.45	3.27	3.37
V	2.70	2.76	2.84	2.86	2.97	2.84	2.51
FE	0.16	0.15	0.15	0.16	0.15	0.16	0.24
O	0.081	0.088	0.087	0.084	0.082	0.114	0.083
C	0.02	0.03	0.02	0.02	0.01	0.009	0.0017
H	0.0023	0.0015	0.0016	0.0029	0.0013	0.0029	0.0005
Y	L/T 0.0005	L/T 0.0005	L/T 0.0005	0.0005	L/T 0.0006	0.0005	0.01
OE	L/T 0.10	L/T 0.10	L/T 0.10	L/T 0.10	L/T 0.10	L/T 0.10	L/T 0.10
OET	L/T 0.40	L/T 0.40	L/T 0.40	L/T 0.40	L/T 0.40	L/T 0.40	L/T 0.40
TI	REMAINDER	REMAINDER	REMAINDER	REMAINDER	REMAINDER	REMAINDER	REMAINDER

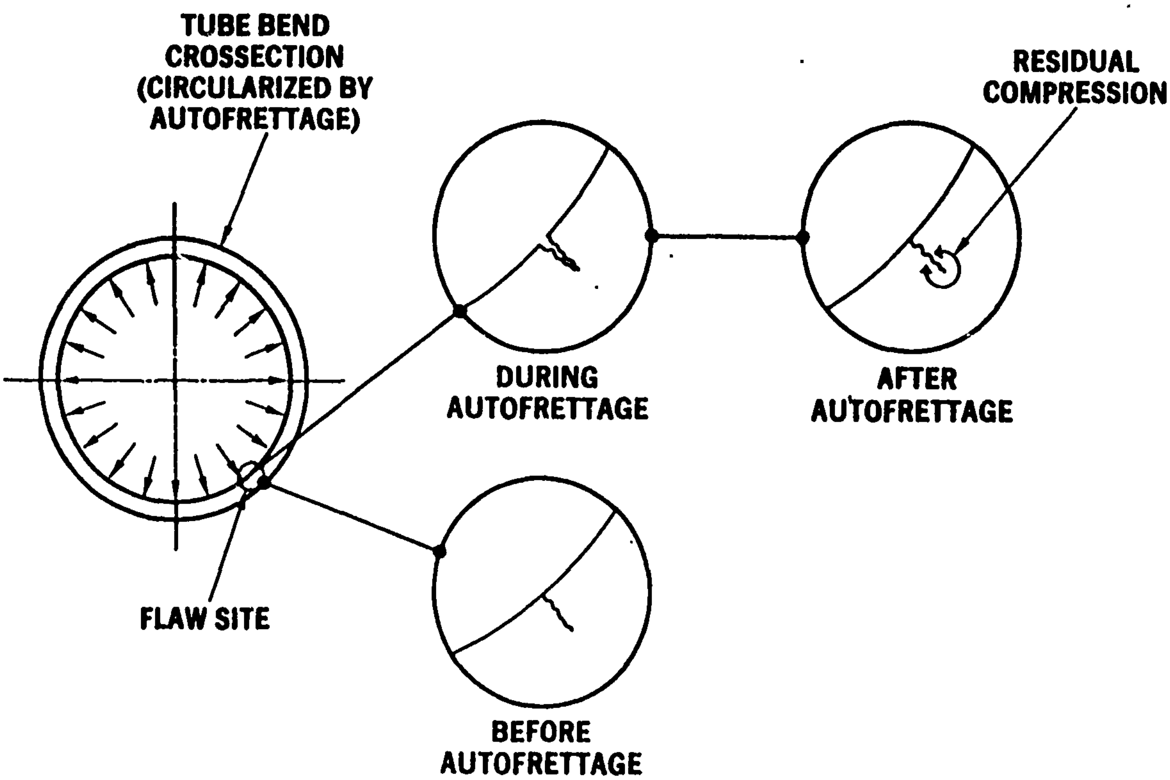


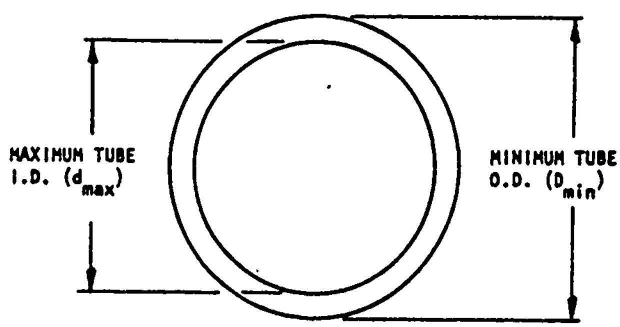
FIGURE 2: AUTOFRETTAGE EFFECT

The pressure required (refer to Table II) in the autofrettage process for complete yielding is computed from the empirical relation shown in Figure 3.

$$P = 0.9\,\sigma_{ult}W$$

where:

P = internal hydrostatic pressure, psi
σ_{ult} = ultimate strength, psi
W = wall ratio (ratio of outside to inside diameter) (Figure 12).



$$W = \frac{D^2_{min} - d^2_{max}}{D^2_{min} + d^2_{max}}$$

D = tube outside diameter
d = tube inside diameter
= (2 x t_{min}) - D
t = tube wall thickness

Figure 3: WALL RATIO ANALYSIS

2.1.2 TRADE STUDIES

Upon completion of the trade studies, the required data from all suppliers were insufficient to draw conclusions based upon normal trade study guidelines. This is primarily because of the limited experience of the various suppliers in supplying 8000 psi aircraft-type hardware/components and the concurrence of design, hardware development, and the requirement for data development. However, most

suppliers provided all available data on their hardware. Pertinent fitting supplier data such as fitting weight, burst pressure, endurance stress level, etc., are included in Table IV. Permanent and detachable fitting suppliers were categorized as shown in Figure 4.

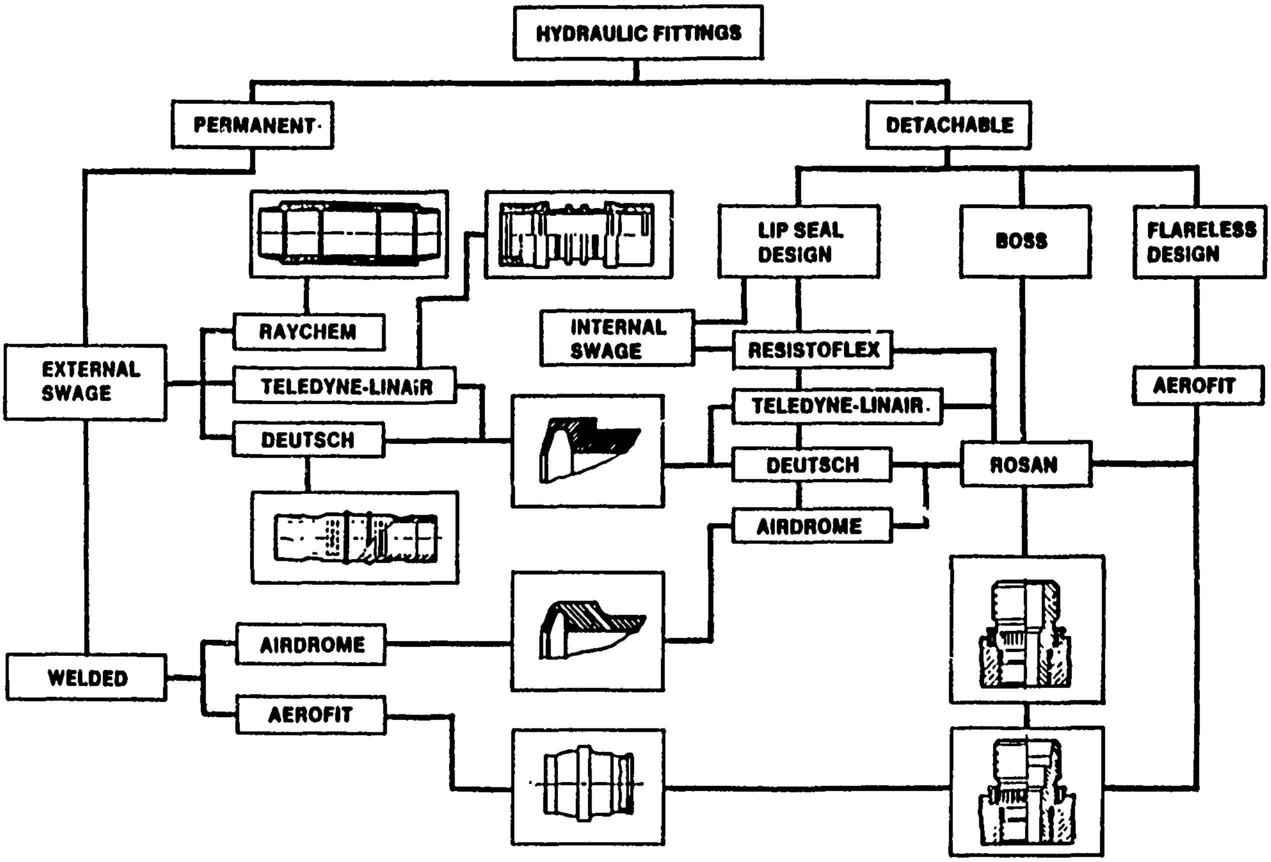


FIGURE 4: FITTING SUPPLIERS CATEGORIZATION

TABLE
TRADE STUDY

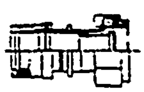
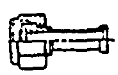
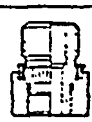
FITTING NAME	DESIGN CONFIGURATION	TYPE OF CONNECTION TO TUBE	INSPECTION METHOD	SEAL TYPE	INSTALLATION	WEIGHT (LBS) 3/16	WEIGHT (LBS) 15/16
Aerofit (Flareless)		Weld tube To fitting	X-Ray	•Curved cylinder type •Metal-to metal	Tube welder (orbit arc type) •Programmer •Power source •Purge gas	--	--
Aeroquip-Linair (Rynglok)		Fxternal swage tube to fitting	•Collar location •Tube •insertion marks	•Lip seal •Metal-to-metal	Swaging tool	.083	.589
Airdrome (Dual seal)		Weld tube to fitting	X-Ray	•Lip seal •Metal-to-metal	Tube welder (Orbit arc type) •Programmer •Power source •Purge gas	--	--
Deutsch (Permaswage)		External swage tube to fitting	•Swage diameter •Tube insertion marks	•Metal-to-metal	External swaging tool	.006	.306
Raychem (Cryofit)		Shrink	•Tube insertion marks	•Metal-to-metal	Hot air source	.011	.411
Resistoflex (Dynatube)		Internal swage tube to fitting	•Swage diameter	•Lip seal •Metal-to-metal	Internal swaging tool	--	--
Rosan		N/A	N/A	•Lip seal •O-ring	Combination wrench drive and extraction tool	.011	.137

TABLE IV
RADE STUDY SUMMARY

WEIGHT (LBS)		TORQUE (IN-LBS)		MATERIAL	SUPPLIER TEST RESULTS		REMARKS
3/16	15/16	3/16	15/16		BURST PRESSURE	FLEX BENDING STRESS AT 10^7	
--	--	95-105	1260-1380	6AL-4V	38,000	-	
.083	.589	60-108	1090-1210	6AL-4V	--	-	•Supplier encountered cracked lip seal test •Second design underway
--	--	60-108	1140-1380	6AL-4V	--	-	
.006	.306	N/A	N/A	Commercially pure titanium	40,000	-	
.011	.411	N/A	N/A	Tinel	39,000	24,000	
--	--	60-108	1140-1380	6AL-4V	25,100	-	
.011	.137	29-36	1055-1170	6AL-4V	--	-	•Fitting is normally tested in conjunction with other supplier's mating lip seal design

Table V shows a matrix of the participating suppliers and their particular products.

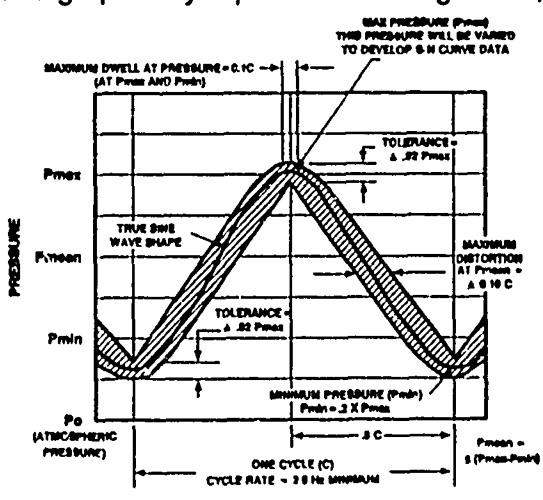
TABLE V
PARTICIPATING SUPPLIERS

DISTRIBUTION SYSTEM HARDWARE	JOINING METHOD	AEROFIT	AEROQUIP	AEROQUIP-LINAIR	AIRDROME	CABOT HAYNES INT.	DEUTSCH	T.A. MFG.	KRUEGER	RAYCHEM	RESISTOFLEX	REXNORD-ROSAN	SEATON-WILSON	SYMETRICS	TITEFLEX
PERMANENT FITTINGS	EXTERNAL SWAGE			X			X								
	HEAT-TO-SHRINK									X					
DETACHABLE FITTINGS	INTERNAL SWAGE										X				
	EXTERNAL SWAGE			X			X								
	WELDED	X			X										
BOSS FITTING		X		X	X							X			
HOSE ASSEMBLY			X												X
SWIVEL ASSEMBLY			X				X		X						
QUICK DISCONNECT			X										X	X	
TITANIUM TUBING						X									

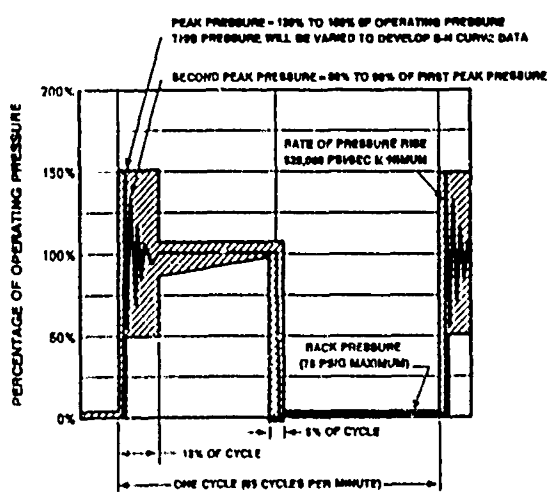
TA MFG - LINE SUPPORTS

2.2 <u>TASK 2 PRESSURE IMPULSE CORRELATION TEST</u>

The objective of the pressure impulse waveform correlation test was to establish a satisfactory correlation between the conventional damped waveform (per Mil-F-18280) and the sine wave impulse test methods shown in Figure 5. The results of this test would provide a comparative damped wave and sine wave database that could be evaluated using a Goodman Constant Life Diagram. The test specimens shown in Figure 6 were identified and installed in the appropriate test set up that would subject them to the required waveform and pressure magnitude defined in Tables VI and VII. Test impulse cycle rate was 65 + 5 CPM for the conventional impulse method and 4.0 $\pm$ 2.0 CPS for the sine wave impulse method. Impulse correlation test results are tabulated in Tables VI and VII and graphically represented in Figures 7, 8, 9.



SINE WAVE

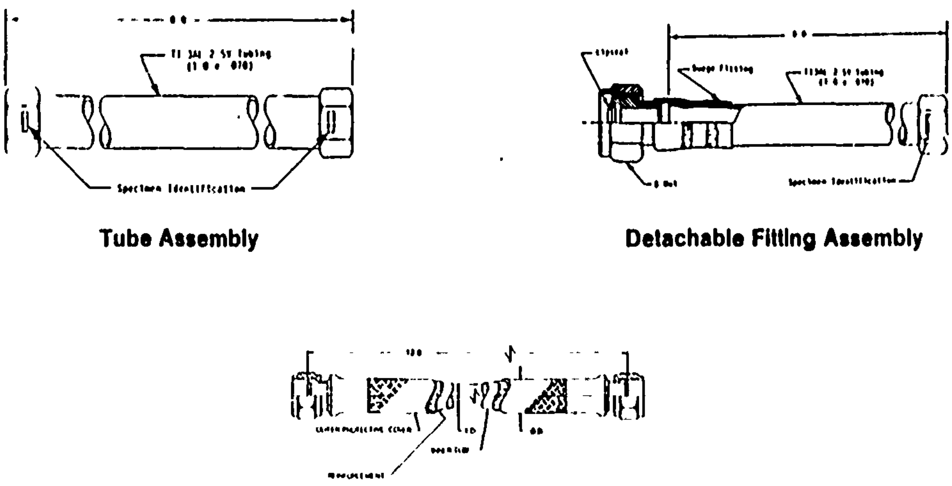


DAMPED WAVE

FIGURE 5: PRESSURE IMPULSE WAVEFORM

It was demonstrated that because of the high rate of rise of the damped waveform (Figure 8), the damped or ringing effect could not be duplicated at high cycle rates. The sine wave (Figure 9) could be induced at a significantly faster rate and it proved to be more reliable , reproducible, and a cost effective test method. An analytical evaluation was conducted on both waveforms (Figures 10 and 11). The analytical conclusion compared favorably to the test results and is summarized in Paragraph 2.2.1.4.

- **Tubing - Haynes International (Cabot)**
- **Detachable fittings - Deutsch**
- **Hose assemblies - Titeflex**



Tube Assembly

Detachable Fitting Assembly

Hose Assembly

FIGURE 6: CORRELATION TEST SPECIMENS

TABLE VI
DAMPED WAVE IMPULSE RESULTS

TEST SPECIMENS	SIZE (INCH)	PART NUMBER	PRESSURE CONDITION THRESHOLD	PEAK	CYCLE COMPLETED	TYPE OF FAILURE
T1 3AL-2.5 TUBING	1.0 x .070	A-CORR-16-070-1	8000	12,000	72,527	TUBE CRACK
		A-CORR-16-070-2	8000	12,000	39,622	TUBE CRACK
		A-CORR-16-070-3	8000	12,000	65,424	TUBE CRACK
		A-CORR-16-070-4	8000	10,000	463,660	TEST STOPPED
		A-CORR-16-070-5	8000	10,000	463,600	TEST STOPPED
		A-CORR-16-070-6	8000	10,000	463,600	TEST STOPPED
CP-T1 DETACHABLE FITTINGS	1.0	B-CORR-16-070-7	8000	10,000	1,171	END FITTING
		B-CORR-16-070-8	8000	10,000	3,841	END FITTING
		B-CORR-16-0[illegible]-9	8000	10,000	2,395	END FITTING
		B-CORR-16-070-10	8000	12,000	516	END FITTING
		B-CORR-16-070-11	8000	12,000	1,825	END FITTING
		B-CORR-16-070-12	8000	12,000	1,825	END FITTING
STAINLESS STEEL HOSE	0.75	C-CORR-12-8K-1	8000	12,000	15,490	END FITTING
		C-CORR-12-8K-2	8000	12,000	16,500	END FITTING
		C-CORR-12-8K-3	8000	12,000	6,435	SWAGE/HOSE
		C-CORR-12-8K-4	8000	10,000	29,217	END FITTING
		C-CORR-12-8K-5	8000	10,000	44,673	END FITTING
		C-CORR-12-8K-6	8000	10,000	36,369	END FITTING
		*C-CORR-12-8K-13	8000	12,000	7,537	SWAGE/HOSE
		*C-CORR-12-8K-14	8000	12,000	5,271	SWAGE/HOSE
		*C-CORR-12-8K-15	8000	12,000	14,600	SWAGE/HOSE

* SPECIAL HIGH PRESSURE END FITTING ATTACHMENT

TABLE VII
SINE WAVE IMPULSE RESULTS

TEST SPECIMENS	SIZE (INCH)	PART NUMBER	MAXIMUM	MINIMUM	CYCLE COMPLETED	TYPE OF FAILURE
Ti 3AL-2.5 TUBING	1.0 x .070	A-CORR-16-070-7	12,000	2,400	295,812	TUBE CRACK
		A-CORR-16-070-8	12,000	2,400	1,990,683	TEST STOPPED
		A-CORR-16-070-9	12,000	2,400	1,990,683	TEST STOPPED
CP-Ti DETACHABLE FITTINGS	1.0.	B-CORR-16-070-1	12,000	2,400	2,683	CRACKED LIP SEAL
		B-CORR-16-070-2	12,000	2,400	1,529	CRACKED LIP SEAL
		B-CORR-16-070-3	12,000	2,400	1,788	CRACKED LIP SEAL
		B-CORR-16-070-1	10,000	2,000	9,109	CRACKED LIP SEAL
		B-CORR-16-070-2	10,000	2,000	10,711	CRACKED LIP SEAL
		B-CORR-16-070-3	10,000	2,000	8,289	CRACKED LIP SEAL
STAINLESS STEEL HOSE	0.75	C-CORR-12-8K-7	10,000	2,000	76,933	END FITTING
		C-CORR-12-8K-8	10,000	2,000	160,384	END FITTING
		C-CORR-12-8K-9	10,000	2,000	99,331	END FITTING
		*C-CORR-12-8K-19	10,000	2,400	403,479	SWAGE/HOSE
		*C-CORR-12-8K-20	10,000	2,400	323,687	BRAID FAILURE
		*C-CORR-12-8K-21	10,000	2,400	326,134	BRAID FAILURE
STAINLESS STEEL HOSE	0.75	C-CORR-12-8K-10	12,000	2,400	70,919	SWAGE/HOSE
		C-CORR-12-8K-11	12,000	2,400	45,637	END FITTING
		C-CORR-12-8K-12	12,000	2,400	46,900	END FITTING
		*C-CORR-12-8K-16	12,000	2,400	161,431	SWAGE/HOSE
		*C-CORR-12-8K-17	12,000	2,400	231,887	BRAID FAILURE
		*C-CORR-12-8K-18	12,000	2,400	194,798	SWAGE/HOSE

* SPECIAL HIGH PRESSURE END FITTING ATTACHMENT

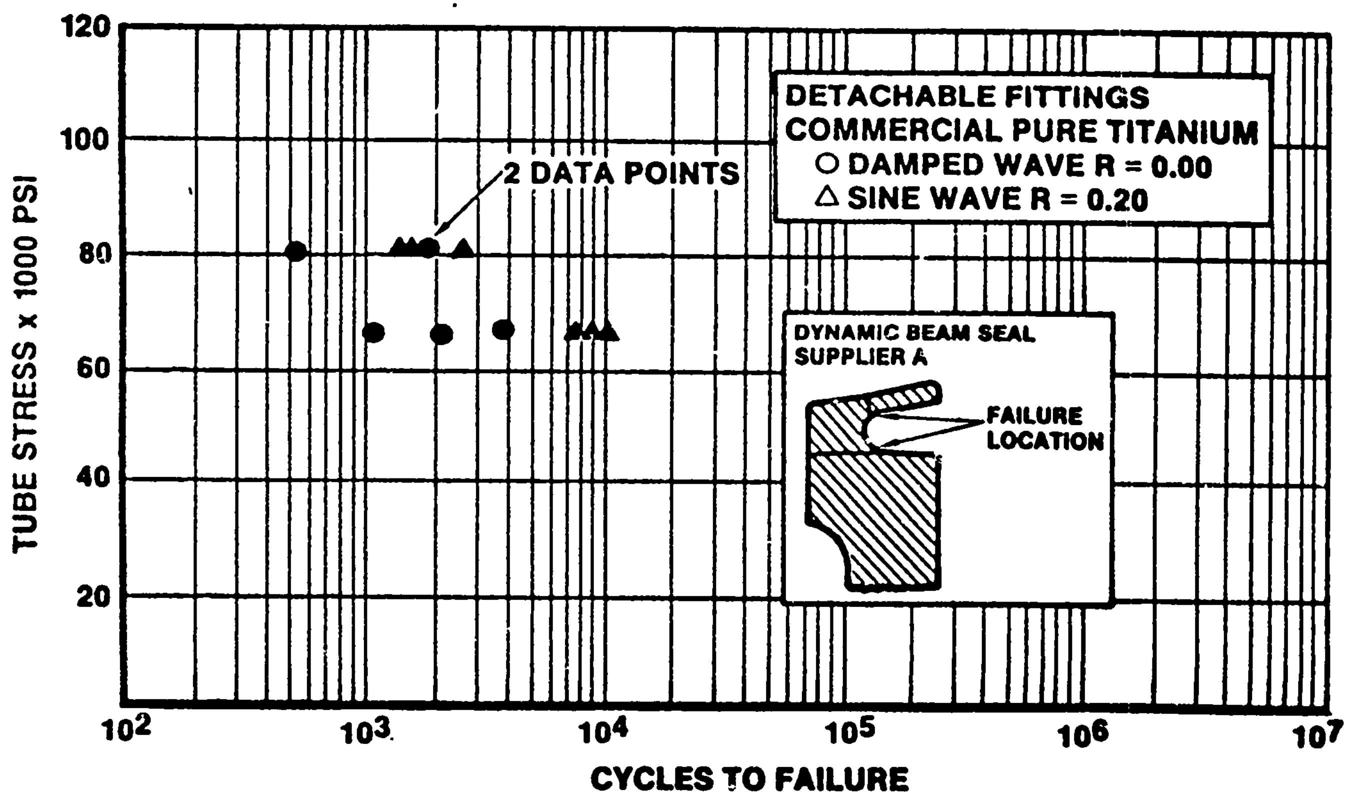


FIGURE 7: DETACHABLE FITTING IMPULSE RESULTS

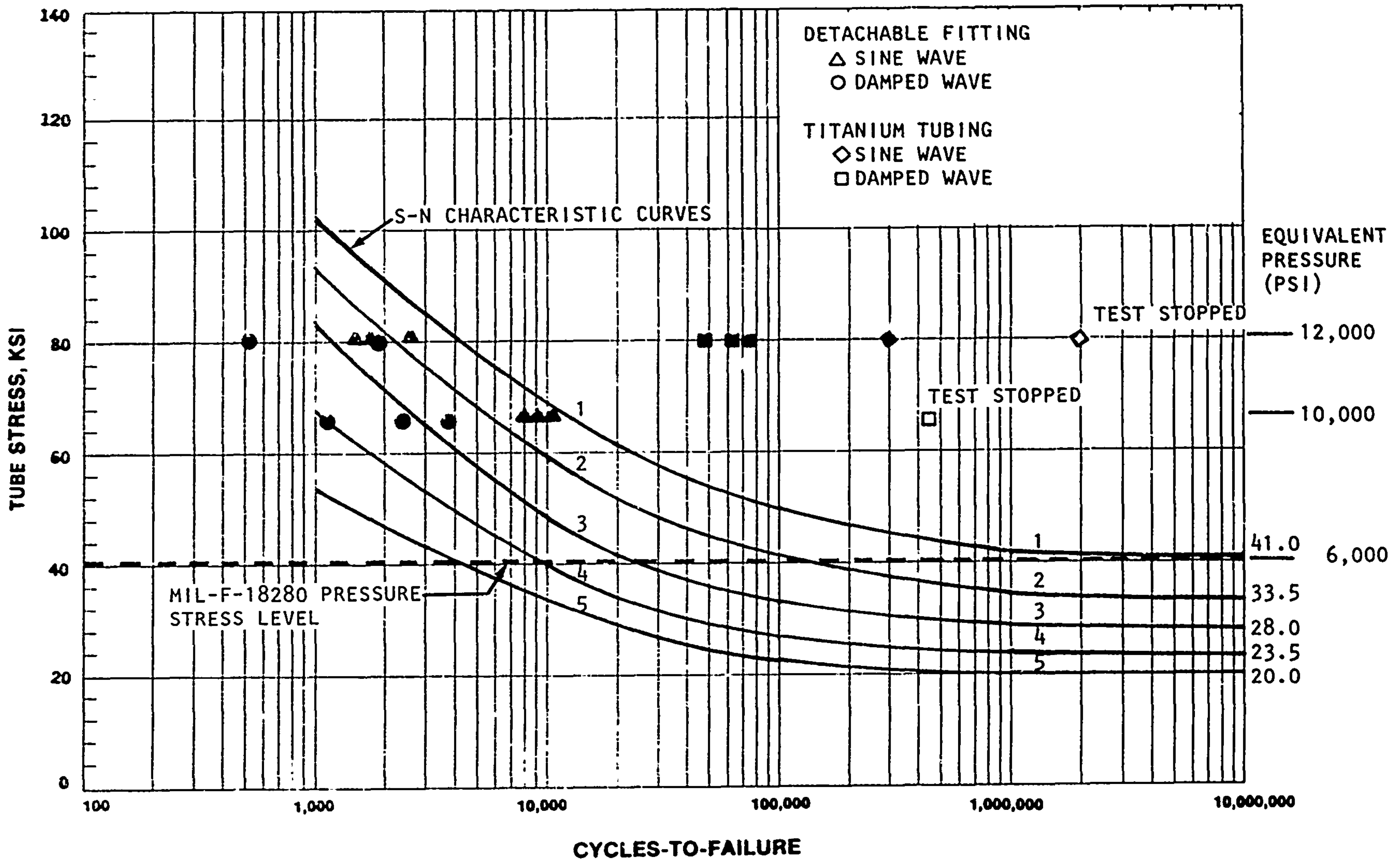
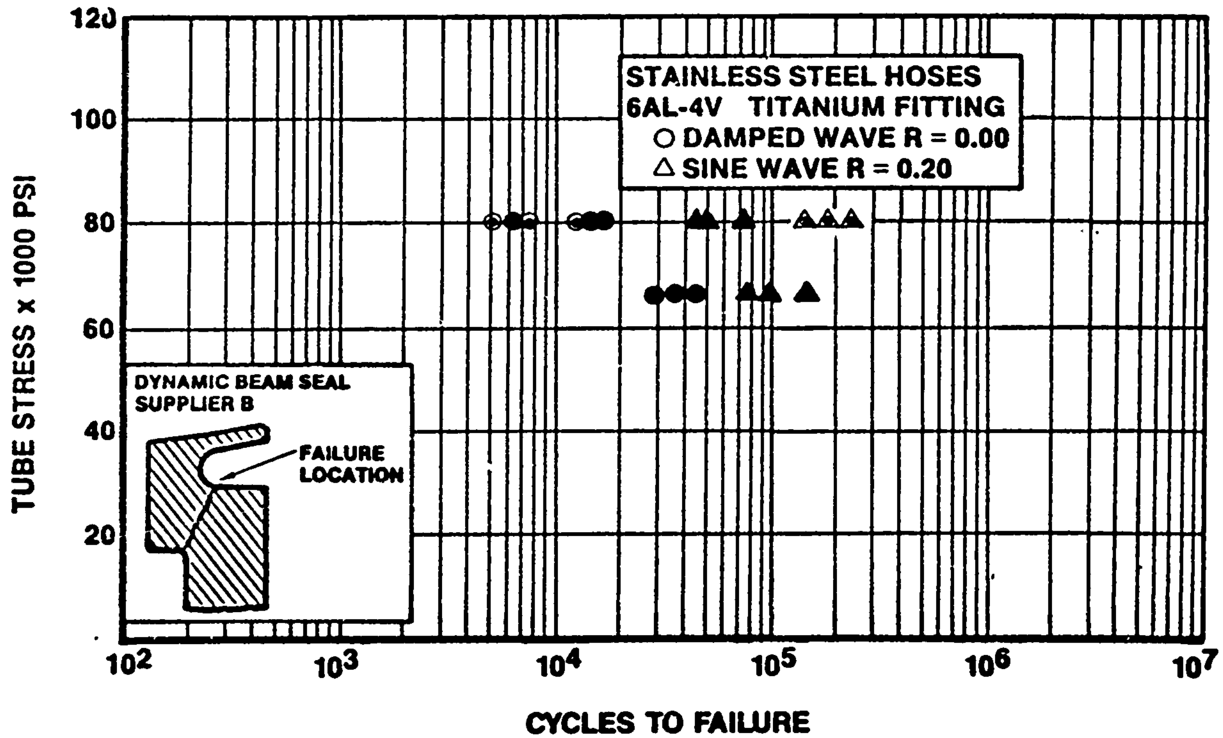


FIGURE 8: TUBING IMPULSE RESULTS



▲ ⊙ WITH SPECIAL HIGH PRESSURE END FITTING ATTACHMENT

FIGURE 9: HOSE ASSEMBLY IMPULSE RESULTS

2.2.1 TEST RESULTS

The impulse testing conducted on this program successfully established a correlation between the sine wave and damped wave test methods. The two test methods produced similar failures in the tubing, detachable fittings and hose assembly. Based on the correlation test results, the sine wave impulse test method was selected for the screening test phase. Two industry standards were issued by the SAE G-3 committee setting a standard for sine wave impulse testing.

AS4265 - Impulse testing of Hydraulic tubing and fittings, S-N Curve.

AIR4298 - Impulse Test Machine, Sine Wave Equipment and Operation

2.2.1.1 Straight Tubing

Testing on the titanium 3AL-2.5V tubing was discontinued since impulse testing of the straight tubing was not a statement-of-work requirement. An evolution of the tubing test data indicates that the performance of the tubing was within the scatterband of an "R" factor of 0.0 and a "R" factor of 0.20 as shown in Figure 10.

The failure mode of the titanium 3AL-2.5V tubing was in the form of a longitudinal crack (refer to Figure 11). A detailed stress analysis was conducted and is discussed in detail in Para 2.2.1.4.

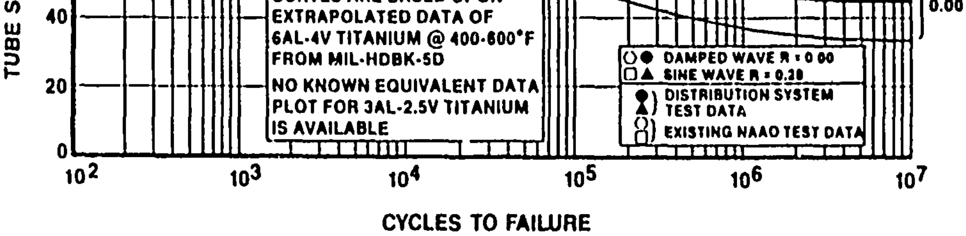


FIGURE 10: TUBING FATIGUE SCATTER BAND

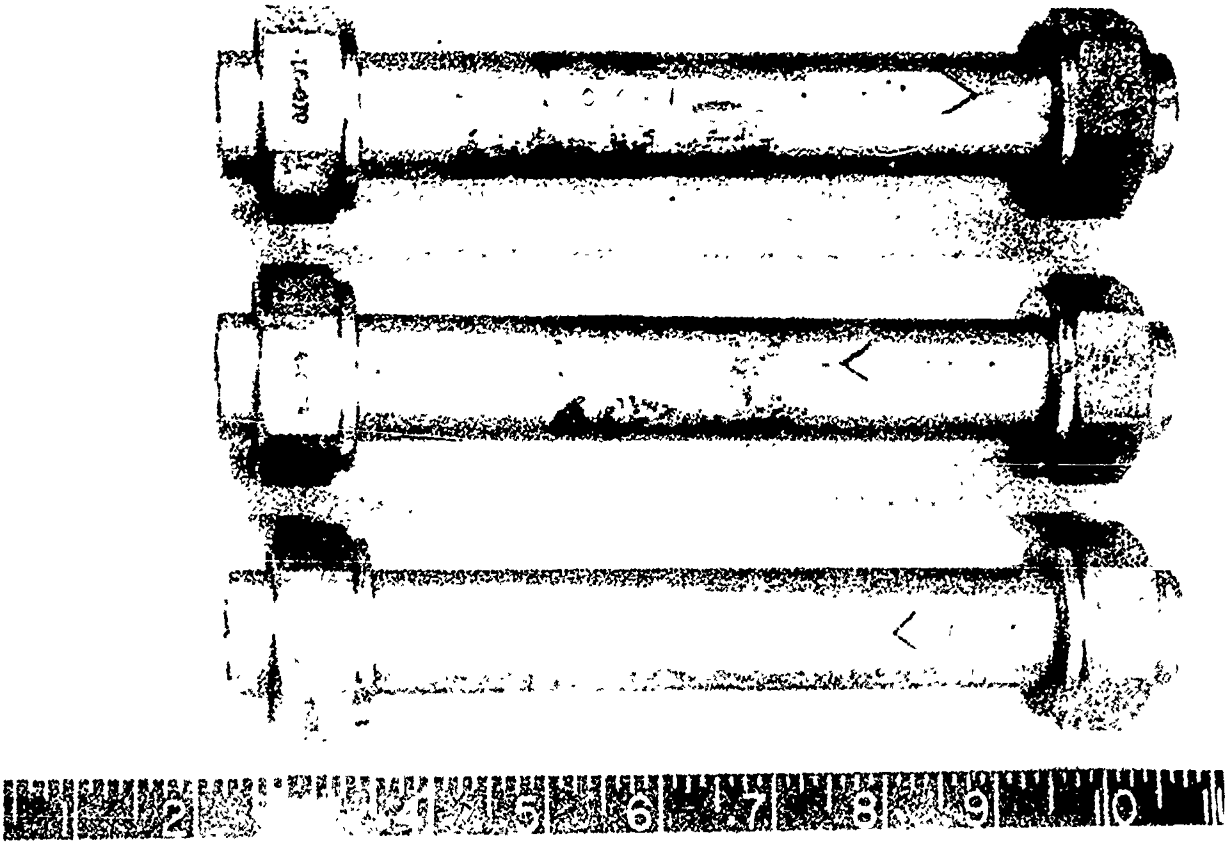


FIGURE 11: TUBING FAILURE MODE

2.2.1.2 Detachable Fittings

Sine-wave and damped-wave impulse testing of the DNR 11200V-16 Permaswage lip seal fitting was at peak pressures of 12,000 psi and 10,000 psi. Refer to Tables VI and VII for the test results and to Figure 7 for a graph of the test results.

The performance of the detachable fittings subjected to the two waveforms was about as projected. The test results indicate good correlation considering the limited number of specimens and the inability to fully fill out a statistically significant scatterband. As expected, the sine-wave test specimens consistently gave longer cycle life than the damped-wave specimen. The spread between the two sets of test results (i.e., sine-wave versus damped-wave) very closely duplicates the spread that was evident in the impulse test conducted on the titanium 3AL-2.5V tubing.

The failure mode of the Permaswage lip seal was in the form of a radial crack in the lip seal (shown in Figure 12). Preliminary indications are that the crack was fatigue in nature and caused by cyclic breathing of the detachable fitting "B" nut and excessive dynamic deflection of the lip seal during impulse cycling (Figure 13).

The only anomaly in the test data that requires investigation is to determine why all sine-wave specimens bulged or cracked whereas only one of the damped-wave specimens showed structural failure while having a lower leakage cycle life. The only apparent explanation is that the sine-wave specimens had a much longer time at maximum stress (introducing a creep phenomena) whereas the dynamics of the damped wave (high rates of pressure rise) caused a dynamic pumping problem after the remaining wires had "brinelled" their way into the shoulders on one side (refer to "failure description" in Table VIII).

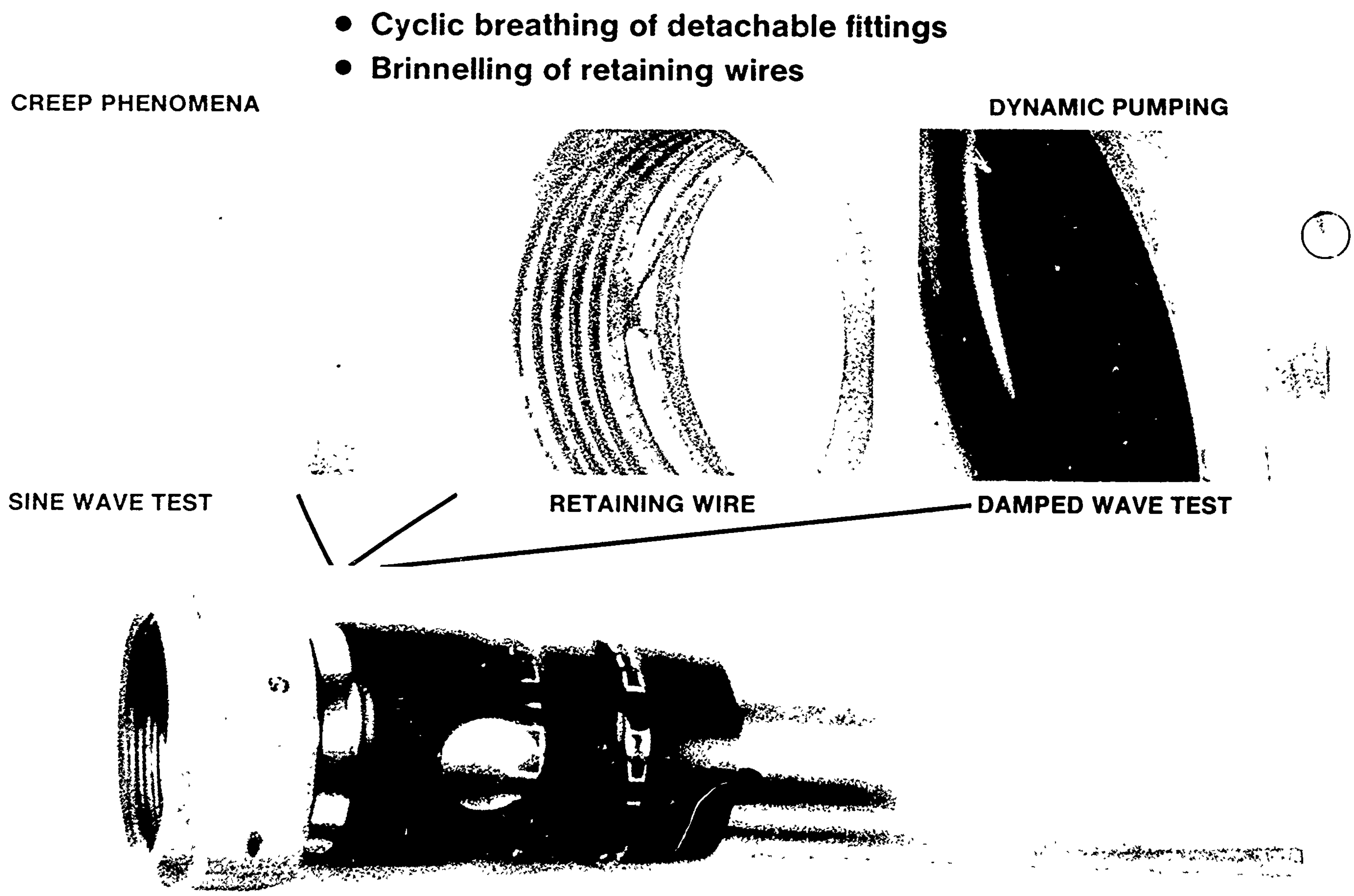


FIGURE 12: LIP SEAL FAILURE MODE

- Cyclic Breathing of Detachable Fittings
  - Low Modulus "B" Nut Material
  - ap Between Sealing Surface

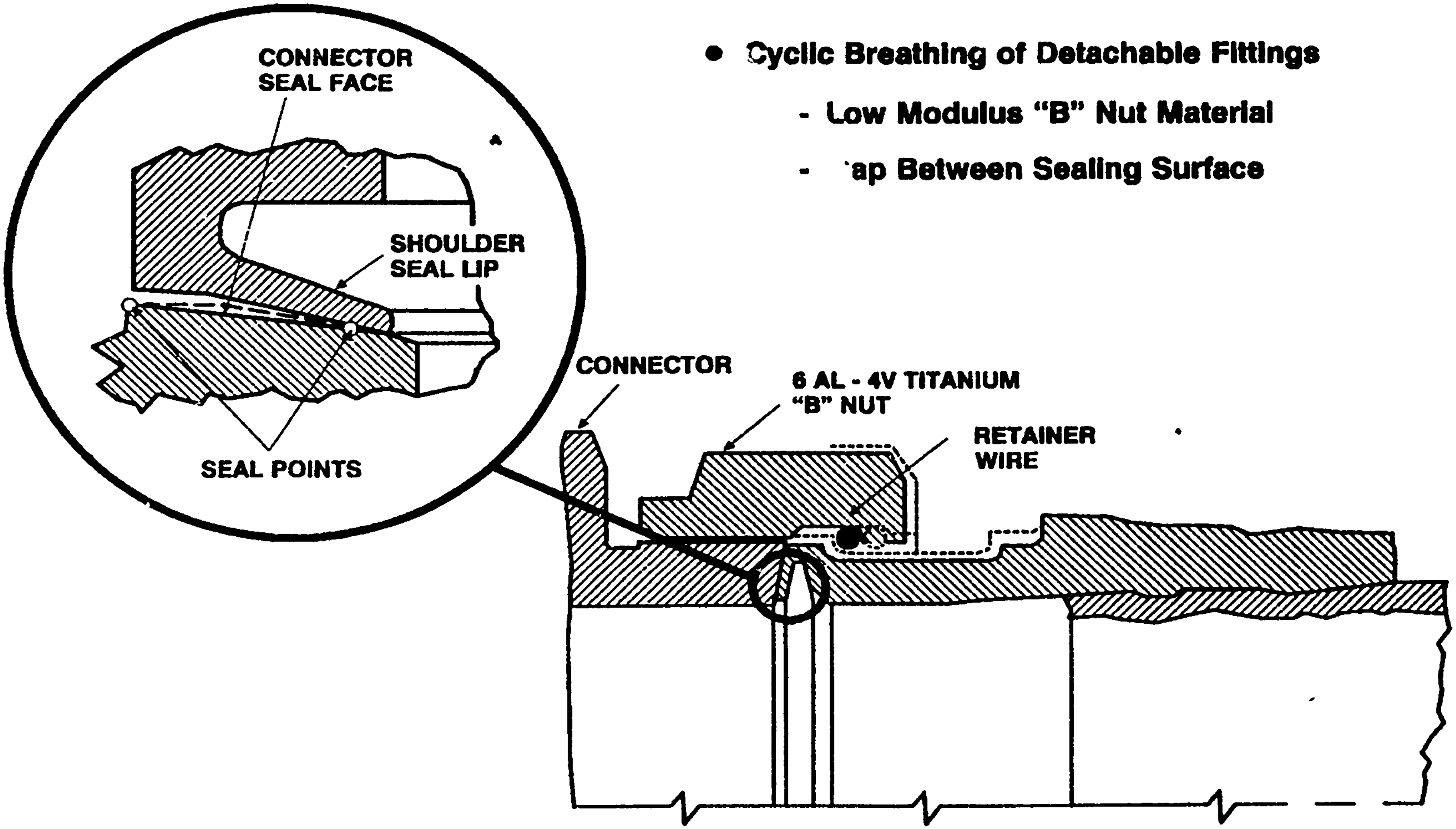


FIGURE 13: CYCLIC BREATHING OF LIP SEAL

TABLE VIII
FAILURE DESCRIPTION

IMPULSE CORRELATION TEST RESULTS - PERMASWAGE DMR 11200V LIP SEAL

SPECIMEN NO.	IMPULSE TYPE	FAILURE DESCRIPTION	PRESSURE RANGE PEAK - MIN (PSI)	IMPULSE CYCLES	AVERAGE CYCLES	REMARKS
1 ⊕	SINEWAVE	FACE BULGED	12,000 - 2,400	2,683		
2 ⊕	SINEWAVE	FACE CRACKED AND BULGED	12,000 - 2,400	1,529	2000	
3 ⊕	SINEWAVE	FACE CRACKED AND BULGED	12,000 - 2,400	1,788		"R" FACTOR = 0.2
4	SINEWAVE	FACE BULGED * (.25)	10,000 - 2,000	9,109		
5	SINEWAVE	** SIDE CRACKED NEAR WIRE DISCONTINUITY * (.10)	10,000 - 2,000	10,711	9,369	
6	SINEWAVE	** SIDE CRACKED NEAR WIRE DISCONTINUITY * (.28)	10,000 - 2,000	8,289		
7 ⊕	DAMPED WAVE	NO DETECTABLE FAILURE	10,000 - 150 8,000 PSI DWELL	1,171		"R" FACTOR = 0.015
8	DAMPED WAVE	** SIDE CRACKED NEAR WIRE DISCONTINUITY * (.13)	10,000 - 150 8,000 PSI DWELL	3,841	2,469	
9 ⊕	DAMPED WAVE	NO DETECTABLE FAILURE	10,000 - 150 8,000 PSI DWELL	2,395		
10	DAMPED WAVE	NO DETECTABLE FAILURE * (.31)	12,000 - 150 8,000 PSI DWELL	516		"R" FACTOR = 0.0125
11	DAMPED WAVE	NO DETECTABLE FAILURE * (.31)	12,000 - 150 8,000 PSI DWELL	1,825	1,389	
12	DAMPED WAVE	SIDE CRACKED NEAR WIRE DISCONTINUITY * (.22)	12,000 - 150 8,000 PSI DWELL	1,825		

* (.XX) SHOULDER DEFORMED (LOCALLY PEENED) AT EDGES OF THE SHOULDER WIRE'S GAP [(.XX) = GAP IN INCHES]

INDICATING NON-UNIFORM SUPPORT OF LIP SEAT

⊕ NUT NOT REMOVED, THEREFORE GAP (.XX) COULD NOT BE DETERMINED

** LOOKING AT LIP SEAL FACE, SIDE BULGE OR CRACK ALWAYS WAS IMMEDIATEL THE LEFT OF GAP

2.2.1.3 <u>Hose Assembly</u>

The performance of the hose assemblies subjected to the two waveforms follows somewhat the same scatter pattern as the tubing and detachable fitting specimens. As projected, the sine-wave test specimens consistently gave longer cycle life than the damped-wave specimens (refer to Figure 9).

Test results indicate that the failure mode of specimens subjected to the damped-waveform are inner core "blow out" which causes the fluid to leak at or near the hose swage interface. Figure 14 is a pictorial view of failures caused by inner core "blow out." On the other hand, the failure mode of specimens subjected to the sine-waveform was consistently a braid failure. Figure 15 shows a braid failure prior to complete rupture. Again, the only explanatory difference between the failure modes (Figure 16) of the specimen subjected to the two waveforms is that the sine-wave impulse test specimens were at maximum stress for a longer a period of time. See Figure 17.

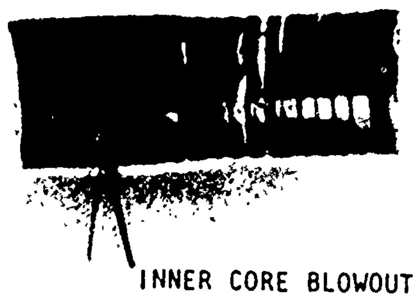


Figure 14A. Hose Fitting Attachment Area

Figure 14B. Innercore Blowout- (Inside View)

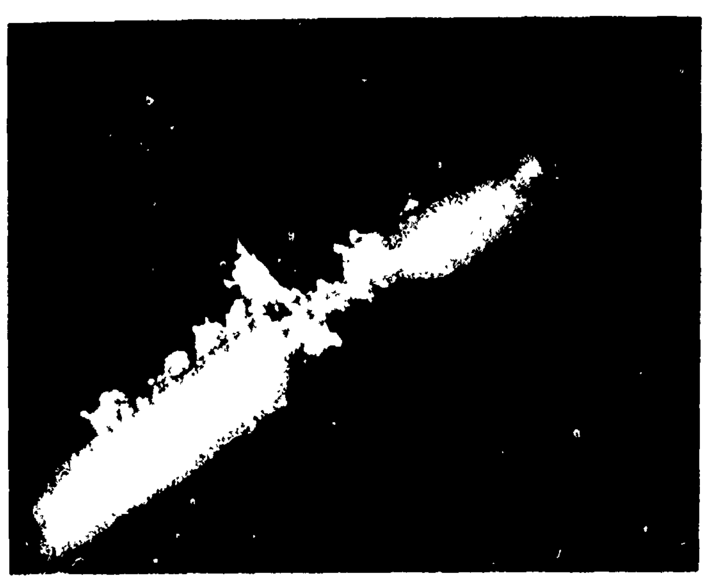


Figure 14C. Cross Section of Innercore Blowout

FIGURE 14: INNER CORE BLOW OUT

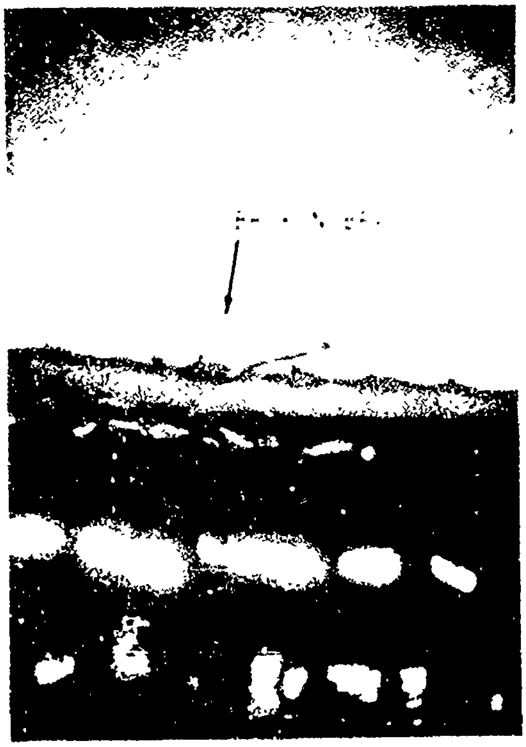


Figure 15A. Innercore Cross Section

Figure 15B. Broken Braid

FIGURE 15: BRAID FAILURE DUE TO SINE WAVE IMPULSE

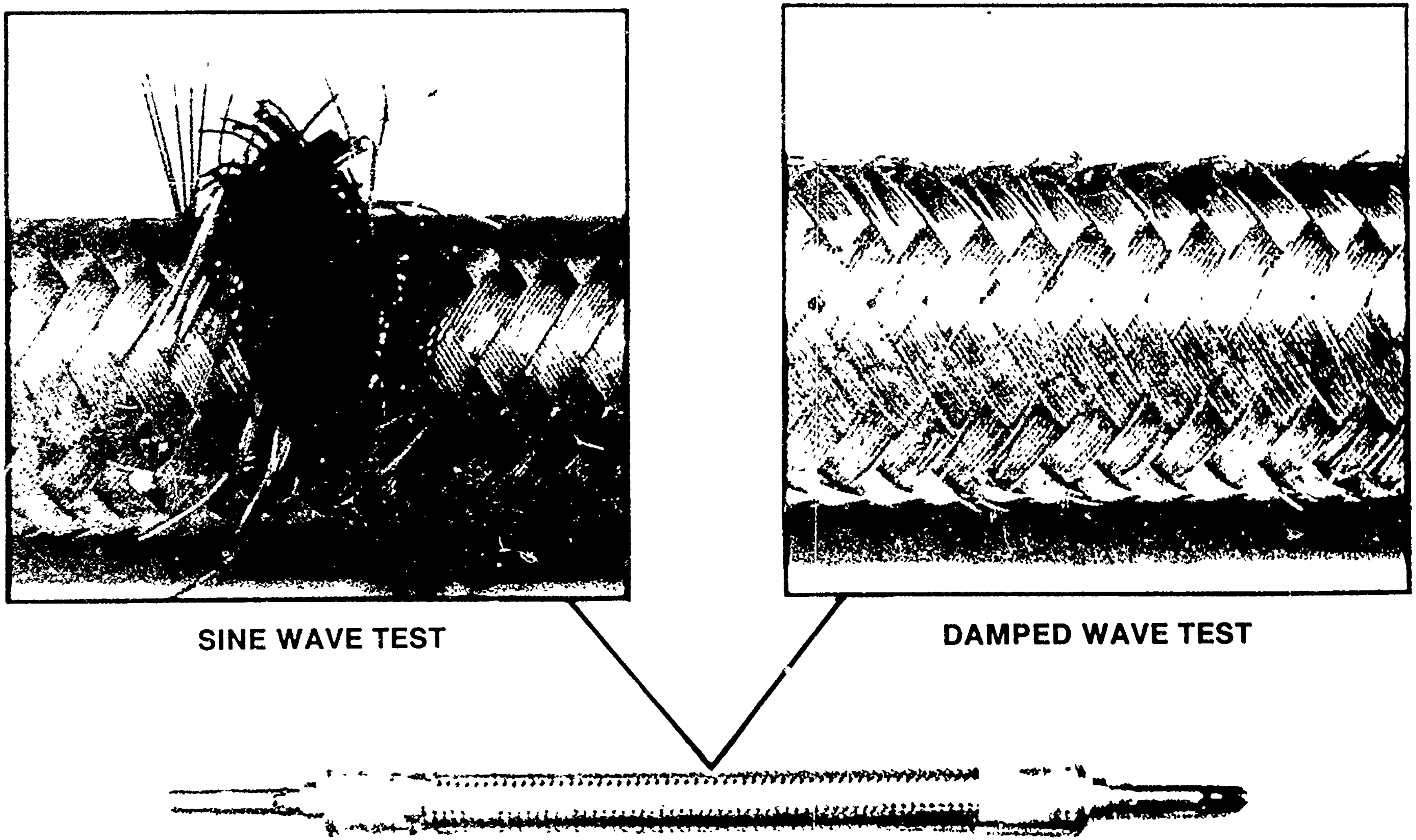


FIGURE 16: HOSE FAILURE MODE

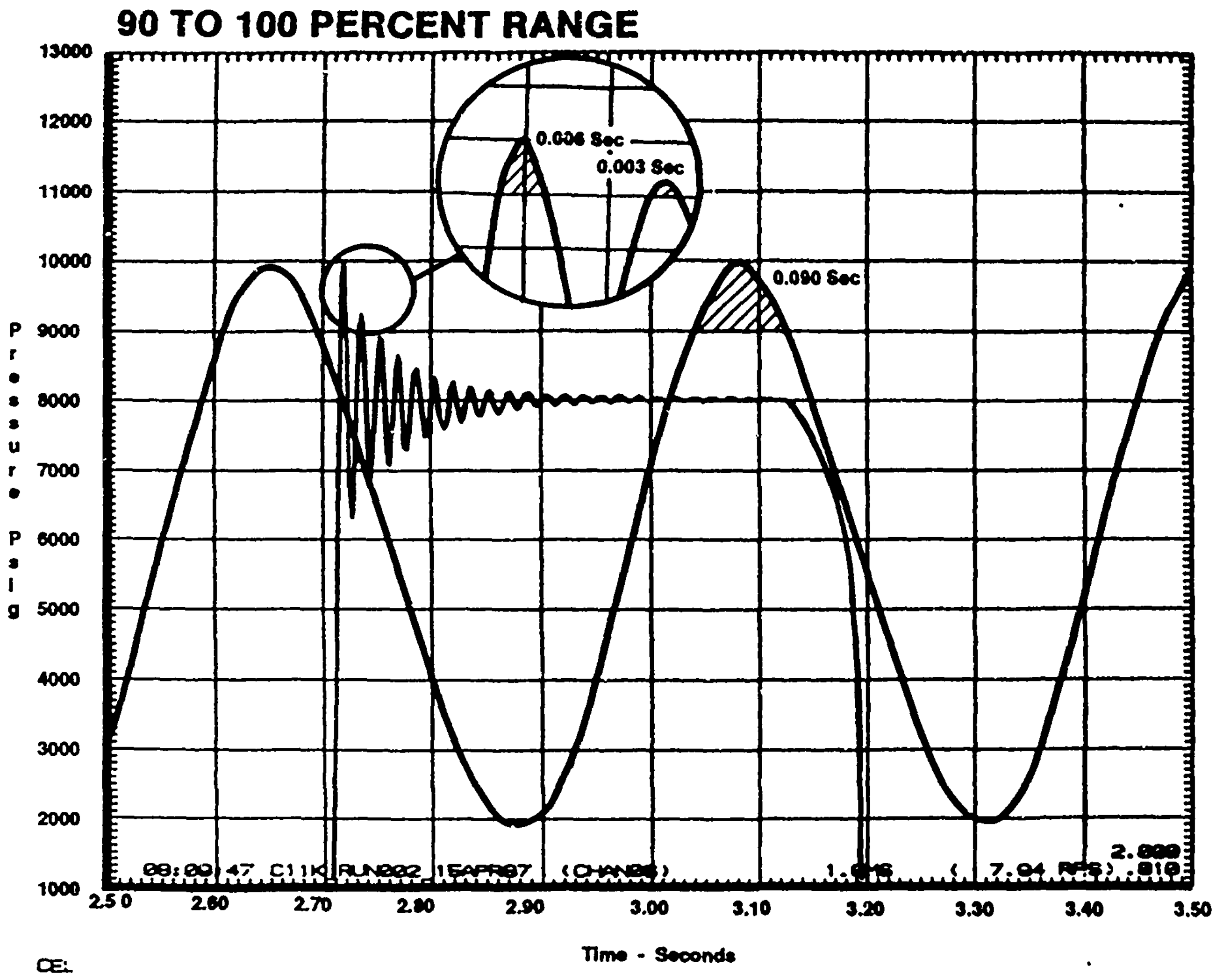


FIGURE 17: PRESSURE PEAK ANALYSIS

2.2.1.4 Tubing Stress Analysis

Testing indicated that hydraulic tubing suffers more rapid and extensive fatigue damage when subjected to damped impulsive pressure wave loading than to a sine wave impulsive pressure loading (Figure 5). Finite element methods were used to generate the comparative transient dynamic stress levels developed in straight hydraulic tubing as a function of loading time.

The basic MAGNA (Material and Geometry Non-Linear Analysis) finite element modeling (FEM) code was used to evaluate and compare the time varying dynamic stress levels developed for sinusoidal and damped impulsive pressure wave loading of the model. A linear dynamic analysis at a constant temperature of 400 °F was conducted.

The MAGNA library of finite element programs was used to quickly and efficiently generate the FEM model via the MAGNA PREPROCESSOR. By symmetry a half model of 4-inch long tubing fixed at one end (as behavior expected of long straight portions of tubing.

The basic natural frequency of the FEM model was evaluated. This natural frequency in turn led to the time increment for proper integration of the dynamic equations of motions and sampling time increment for dynamic response.

The FEM model was subjected to 0.50 seconds of dynamic pressure loading where both sinusoidal and damped pressure waveforms showed overall maximum and minimum loading amplitudes. Both dynamic stress level outputs from the main MAGNA program were in turn processed by the MAGNA Postprocessor. Stress contours were generated for both loading cases over the 0.50 seconds of loading investigated. See Figures 18 and 19.

Reflecting the tabulated pressure waveform test data, generally higher stress levels over longer time spans were seen for sinusoidal pressure wave loading. Though not achieving the same high levels of stress except initially, the damped waveform produced rapidly oscillating stress levels especially in the first 0.20 seconds of non-zero loading. The gradual stress variation of the sinusoidal case may be considered as a single cycle phenomenon. On the other hand, the rapid damping oscillations may be viewed as separate secondary components of an effectively multicycle oscillation.

To properly correlate the effect of pressure waveform dynamic loading upon a hydraulic tubing test specimen with predicted specimen behavior, the fatigue factor must be strongly considered.

Four separate factors will determine the effect on fatigue life for specimens experiencing oscillatory levels of pressure pulse induced dynamic stress:

1) Range of Stress--variation of stress between minimum and maximum sinusoidal pulse varies from 2400==>12000 psi. Damped pulse varies from 0==>12000 psi.

2) R (retreat) factor--ratio of minimum stress to maximum stress sinusoidal pulse R factor = 2400/12000 = 0.2 damped pulse R factor = 0/12000 = 0

3) Number of Cycles -- (primary and secondary) sinusoidal pulse has one primary cycle only. Damped pulse has one primary and multiple number of secondary cycles.

4) Rate of pressure rise--Sinusoidal pulse pressure rate = 60,000 psi/sec. Damped pulse pressure rate = 1,300,000 psi/sec.

Each one of the preceding fatigue factors markedly point to the superior fatigue performance of sinusoidal over damped pressure pulse loading.

A comparative dynamic stress analysis of analytically modeled straight hydraulic tubing has successfully mirrored test results for sinusoidal and damped pressure pulse loading. The damped pressure pulse loading tested is more destructive fatigue-wise than the tested sinusoidal pressure pulse.

EFFECT OF WAVEFORM – FINITE ELEMENT

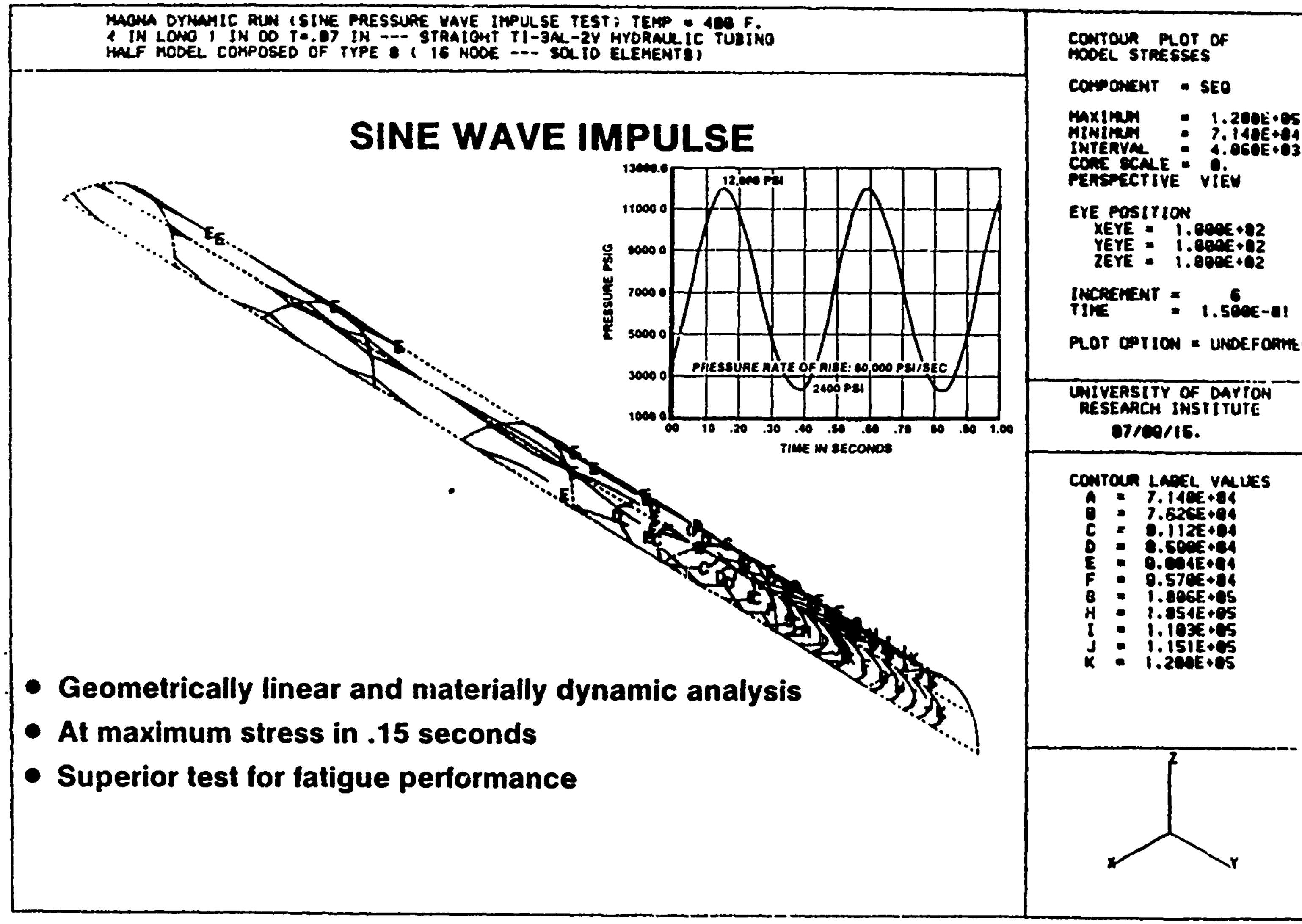
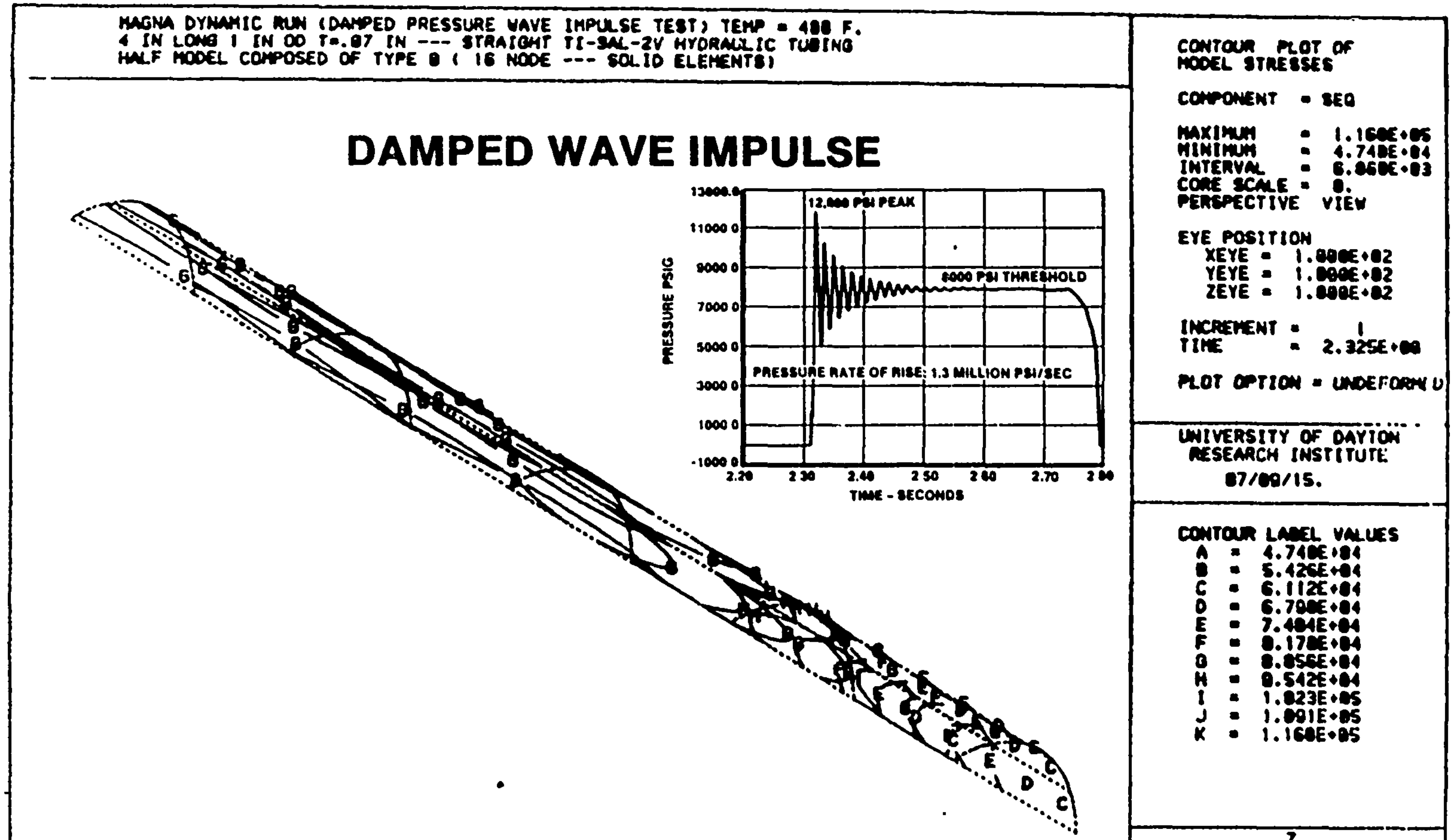
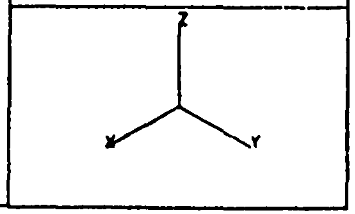


FIGURE 18: SINE WAVE WAVEFORM ANALYSIS

EFFECT OF WAVEFORM – FINITE ELEMENT





- Geometrically linear and materially linear dynamic analysis
- At maximum stress in 0.025 seconds
- Inferior test for fatigue performance

FIGURE 19: DAMPED WAVE WAVEFORM ANALYSIS

3.0 SCREENING TESTS

With an objective to conduct S-N type pressure impulse tests on hydraulic fittings, hoses, quick disconnects and swivel assemblies, this task provides basic design data and defines the dynamic endurance limits of the various components. A comparison between like components is based on their S-N performance.

3.1 SCREENING TEST HARDWARE

The test hardware is listed by suppliers in Table V.

3.2 SINE WAVE IMPULSE TEST

The sine-wave impulse test was conducted on 3/16 and 15/16-inch test hardware. Test data (in the form of S-N curves) are included as an Appendix A to this report.

3.2.1 PRESSURE IMPULSE TEST

The pressure testing using 3/16-inch fitting/tube assemblies was initiated. The initial impulse levels were 20,000 psig maximum peak (Pmax) pressure and 2400 psig minimum peak (Pmin) pressure. This test level represents testing at an R-factor of 0.20.

The 20,000 psig represents a tube pressure stress of 79,580 for 3/16-inch tube assemblies and 83,120 psi for 15/16-inch tube assemblies when calculated by the equation.

$$S = P \frac{D^2 + d^2}{D^2 - d^2}$$

WHERE
S = Pressure stress (psi)

P = Internal pressure (psig)
D = Outside tube diameter (inches)
= 0.1875 for 3/16-inch
= 0.9375 for 15/16-inch
d = inside tube diameter (inches)
= 0.1455 for 3/16-inch
= 0.7335 for 15/16-inch

These pressure stress levels were selected to assure the probability of a tubing or fitting/joint failure prior to the test specimen reaching 200,000 pressure impulse cycles. This decision was based (primarily) on the

projected performance scatterband of titanium 3A1-2.5V tubing shown in Figure 10. However, this pressure stress level did not produce failures in the fittings or fitting joints but in the 3/16-inch tubing. The tubing was evaluated for burst strength at room temperature and at 400 °F. It was determined that the relative difference between the burst pressure at room temperature and at 400°F was the same as the relative difference in decreased ultimate strength of titanium 3AL-2.5V at room temperature and at 400°F (Figure 20). The consistent structural performance coupled with the performance of the tube within the predicted scatterband (Figure 10) is an indication that the tubing was manufactured to specification.

The failure of the 3/16-inch tubing fitting is an indication that the smaller diameter fittings are designed to meet other design considerations such as clamping force, minimum tube wall thickness, minimum machining tolerance, minimum swage cross section, and torsional and flexural design requirements. Therefore, the 3/16-inch fittings and fitting joints are much stronger in impulse fatigue than the actual mating tube. A survey of all fitting suppliers indicated that because of these other design considerations, the 3/16-inch fitting will actually withstand internal pressures of 40,000 psig.

By Air Force agreement, no further testing on 3/16-inch tube/fitting assemblies was conducted.

3.2.1.1 Tubing Failures

The tubing failures followed projected S-N fatigue scatterband and are shown in Figure 10. The initial screen test plan was for each fitting supplier to attach his fitting that was cut to lengths from the same lot of tubing material that had been purchased in accordance with Rockwell Specification L272C8000. The 3/16-inch tube/fitting assemblies supplied by Aeroquip-Linair, however, were fabricated from 3A1-2.5V titanium tubing purchased under Navy Specification LHS-8042A. The Navy tubing is presently performing ten times better in fatigue than the tubing purchased to the Rockwell specification (see Figure 21).

EFFECT OF TEMPERATURE ON MECHANICAL PROPERTIES

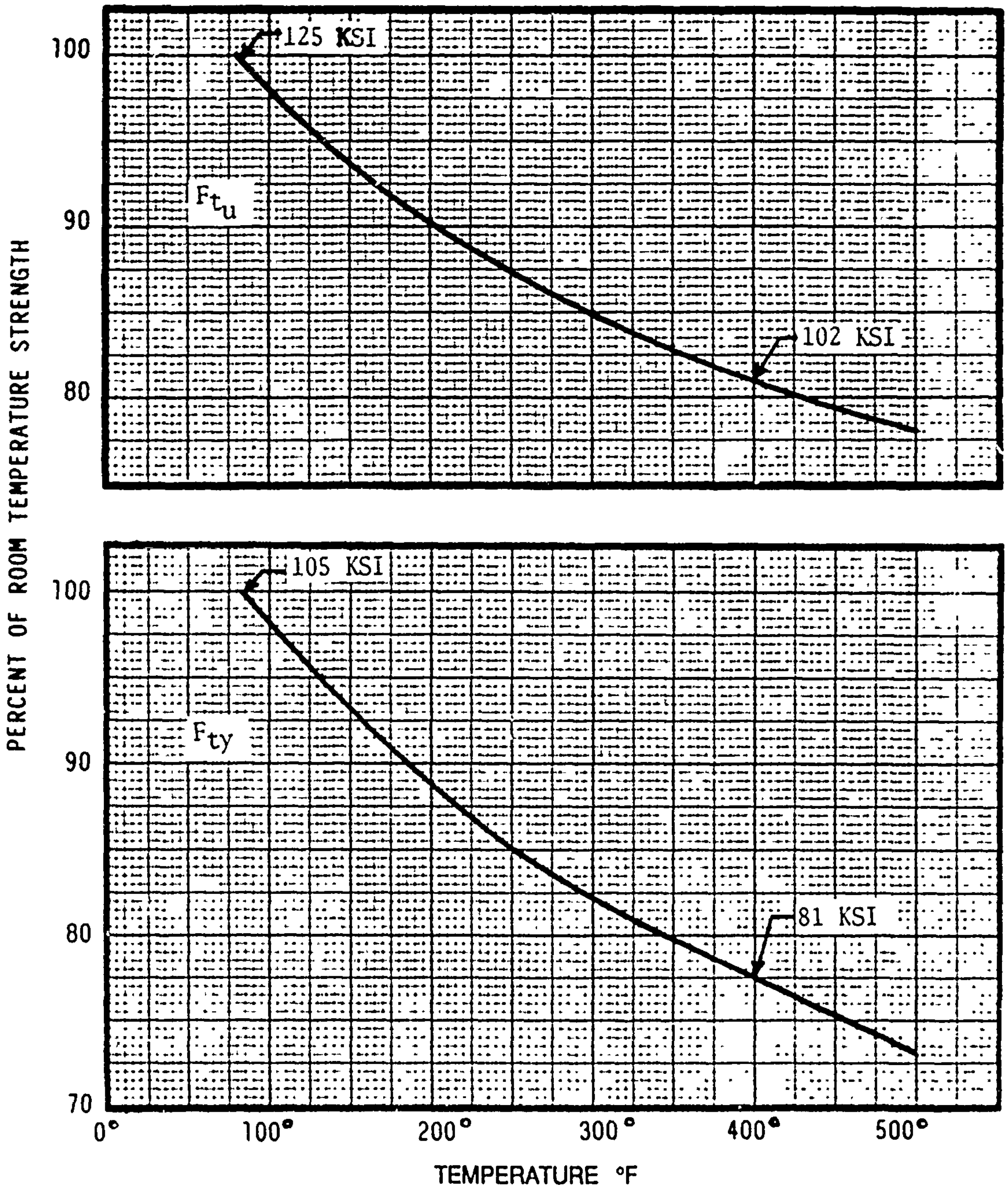


FIGURE 20: TITANIUM 3AL - 2.5V PROPERTIES

- 3/16 fitting/tube assembly
  - Not developing fitting failures
- Tubing performed to projected scatterband at an R-factor of 0.20
  - MIL-HDBK-5D (Ti-6AL-4V @ 400-600° F)
  - KT = 1.0

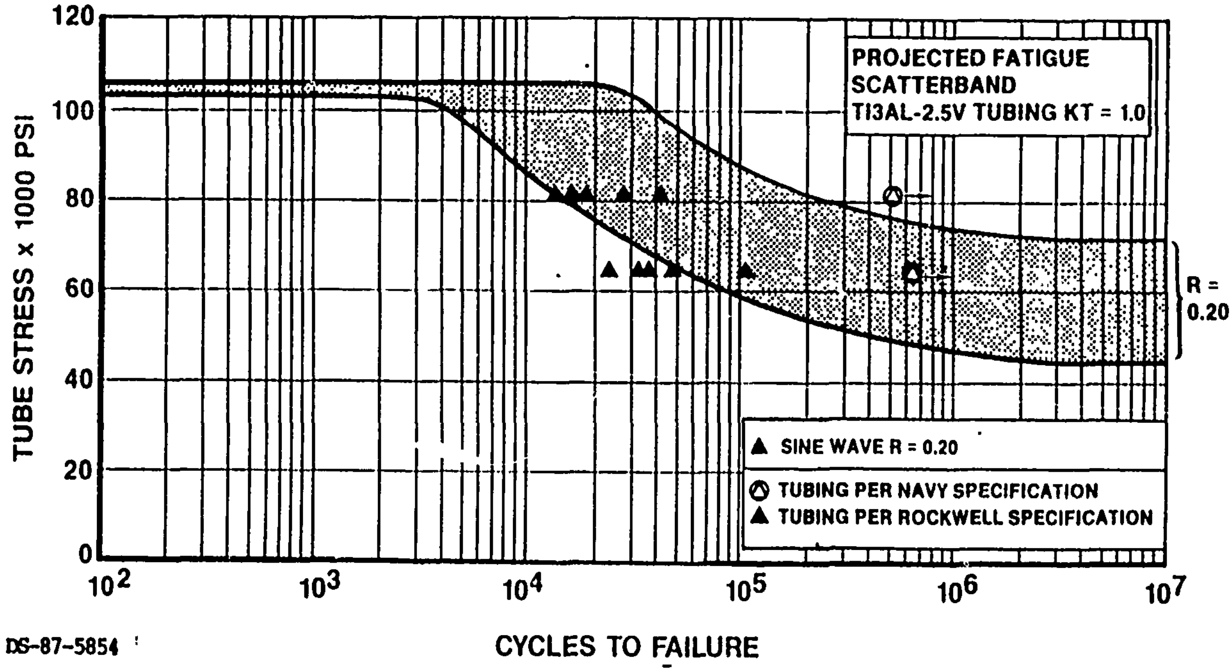


FIGURE 21: TUBING IMPULSE PERFORMANCE

This difference in tubing performance was investigated. It was believed that the tubing purchased under the Navy specification was textured in such a manner that the impulse fatigue life was improved.

Research conducted by Sandvik Special Metals indicates that the fatigue endurance increases as the texture become more radial. (See Figure 22)

FLEXURE FATIGUE S-N CURVE

1/2".X 0.035" Ti-3-2.5 TUBING

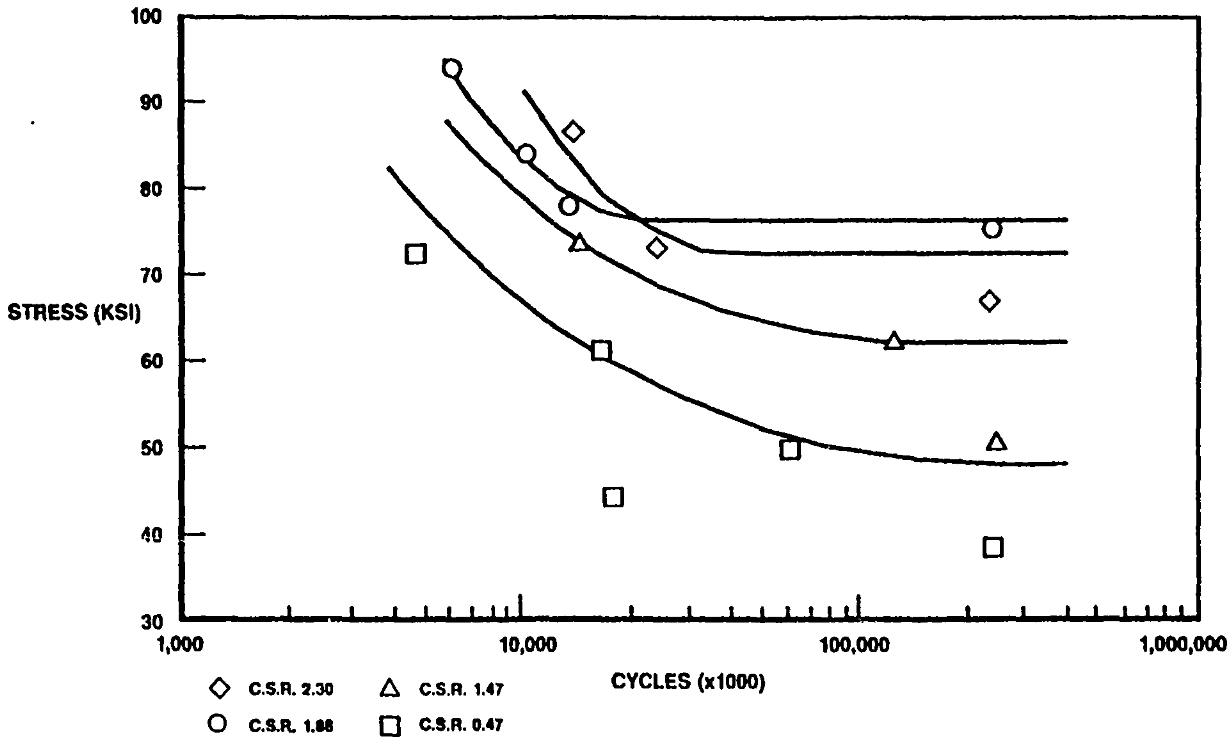


FIGURE 22: EFFECTS OF CRYSTALLOGRAPHIC TEXTURE ON TITANIUM TUBING PERFORMANCE

The test conducted by Sandvik-Special Metal gave index of a tube's crystallographic texture which is called the contractile strain ratio (CSR). The CSR number increases with the fraction of crystals oriented in the radial direction and decreases when the crystals are oriented in the circumferential direction. Figure 23 shows the orientation of the crystal planes for high and low CSR values.

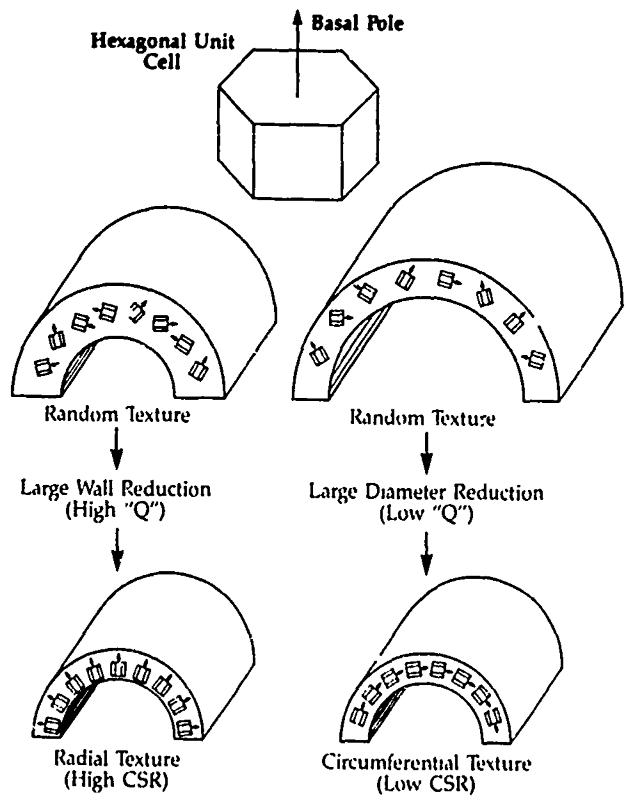
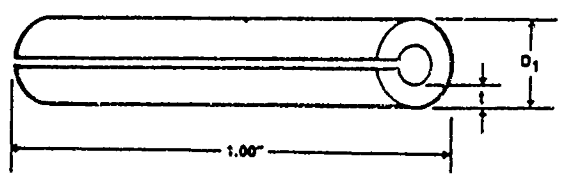


FIGURE 23: EFFECTS OF TUBE REDUCTION ON TUBING PERFORMANCE

The tubing was evaluated for the effect of Residual Stress on Tubing Life. As a result of that evaluation, it was determined that distortion that may occur in the manufacture of tubing can leave residual stress in the surface layer. Compressive residual stress on the inner surface of the tubing wall extends the impulse fatigue life of the tube. This condition must be carefully evaluated because the residual compressive stress on the inner layers is balanced by a residual tensile stress on the outer layers. This condition has a potential for reducing the tubing life when subjected to other loading conditions.

The lots of tubing fabricated to LHS-8042A and L272C8000 were evaluated for burst pressure, fabrication techniques and residual stress. The burst pressure was equal for both lots of tubing. However, it was revealed by the tubing manufacturer (Haynes International) that the difference between the two lots of tubing was in the fabrication technique. While the Rockwell tubing was cold rolled to its final diameter, the Navy tubing was cold rolled to an intermediate diameter and then drawn to the final diameter. The two tubing lots were tested for residual stress using the Cranston Method and the Navy tubing was found to have five times the residual compressive stress of the Rockwell tubing as shown in Figure 24.



TUBE PROPERTIES

ITEM	ROCKWELL SPEC	NAVY SPEC
ULTIMATE TENSILE STRENGTH	136,800 (AVERAGE)	125,200 TO 126,500
YIELD STRENGTH	113,300 (AVERAGE)	102,800 TO 103,600
ELONGATION	10.3 (AVERAGE)	10.5 TO 10.8
FINAL HEAT TREAT	4 HRS @ 850° F	4 HRS @ 800° F

AVERAGE RESIDUAL STRESS (psi)

ROCKWELL SPEC = 1,377   NAVY SPEC = 5,098

$$S_T = \frac{ET}{1-\mu^2}\left(\frac{1}{D_0}-\frac{1}{D_1}\right)$$

S_T = RESIDUAL STRESS
E = MODULUS OF ELASTICITY
μ = POISSON RATIO
t = WALL THICKNESS
D_0 = O.D. BEFORE SPLITTING
D_1 = O.D. AFTER SPLITTING

FIGURE 24: RESIDUAL STRESS MEASUREMENT

3.2.1.2 Detachable Fittings

Impulse testing was conducted on the detachable fittings supplied by Aerofit, Aeroquip-Linair, Airdrome and Resistoflex. A comparison of the individual supplier performance is shown in Appendix B. The primary

failure of the tube/fitting interface (Figure 26) of the Aeroquip-Linair Rynglok fitting. The primary failure mode in the Aerofit flareless sleeve (Figure 27) was in the weld joint.

3.2.1.3 Permanent Fittings

Impulse testing was conducted on the permanent fittings supplied by Deutsch and Raychem. A comparison of individual supplier performance is shown in Appendix B. The primary failure mode of the 3/16-inch size continued to be the "classical" tubing fatigue failure. The failure mode of the 15/16-inch size was in the fitting as shown in Figures 28 and 29.

3.2.1.4 Hose Assemblies

Impulse testing was conducted on 3/16-inch and 15/16-inch hose assemblies supplied by Titeflex; a 15/16-inch hose supplied by Aeroquip was also tested. A comparison of the individual supplier's performance is shown in Appendix B. Typical failure modes are shown in Figure 30.

3.2.1.5 Swivel Assemblies

Impulse testing was conducted on the 3/16-inch swivels supplied by Aeroquip and Krueger. Testing of the 15/16-inch swivels was not initiated because of poor performance of the 15/16-inch lip-seal fitting which has not demonstrated sufficient life expectancy when the fitting was tested in conjunction with the 15/16-inch swivel. The primary failure mode of the 3/16-inch swivels resulted from fluid leakage of the rotary seal (Figure 31 and 32). A comparison individual supplier performance is shown in Appendix B.

3.2.1.6 Quick Disconnects

Impulse testing was conducted on the 3/16-inch quick disconnects supplied by Aeroquip, Symetrics and Seaton-Wilson. Again, testing of the 15/16-inch size was delayed pending the development of a satisfactory mating lip-seal design. The primary failure mode of the 3/16-inch quick-disconnects has been structural (Figures 33 and 34). A comparison of the individual supplier performance is included as Appendix B.

3.3 VIBRATION FLEXURE

In an attempt to evaluate permanent and detachable fittings in low-stress, high-cycle environment, NAA conducted vibration fatigue tests to get an indication of how these fittings would perform in a high-vibration area of actual aircraft installations.

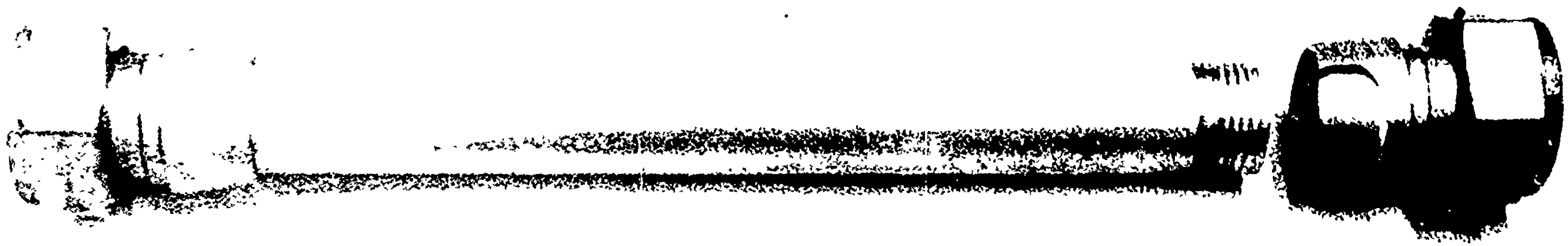


FIGURE 25: RESISTOFLEX FITTING COLLAR FAILURE

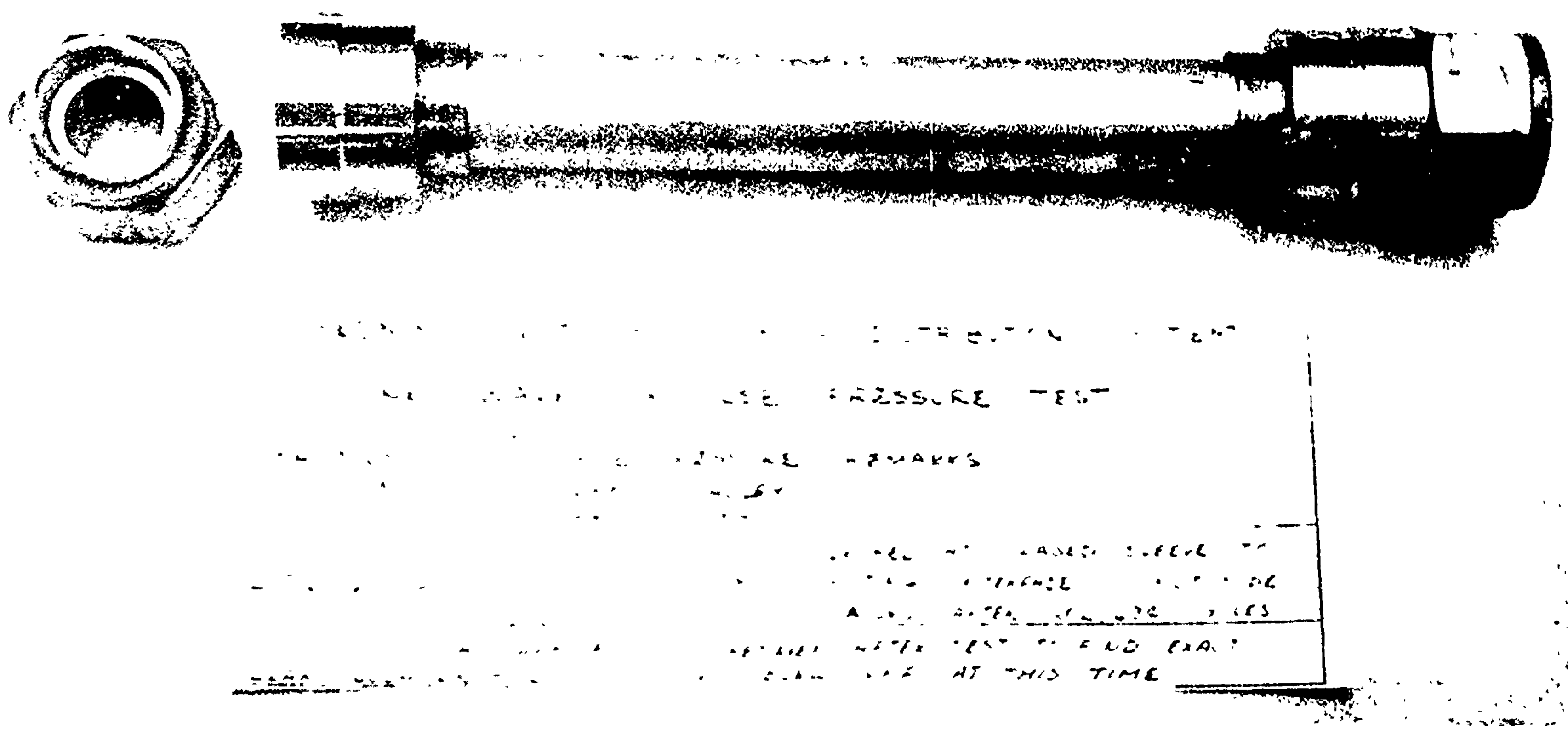


FIGURE 26: AEROQUIP-LINAIR TUBE/FITTING INTERFACE FAILURE

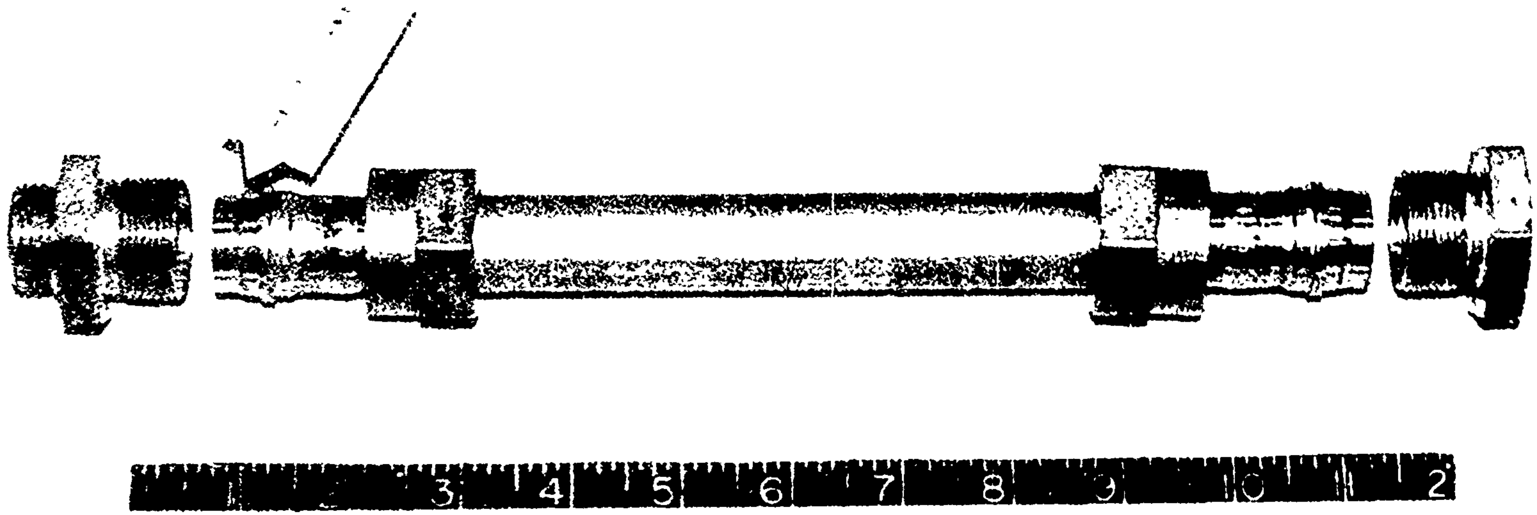


FIGURE 27: AEROFIT FLARELESS FITTING FAILURE

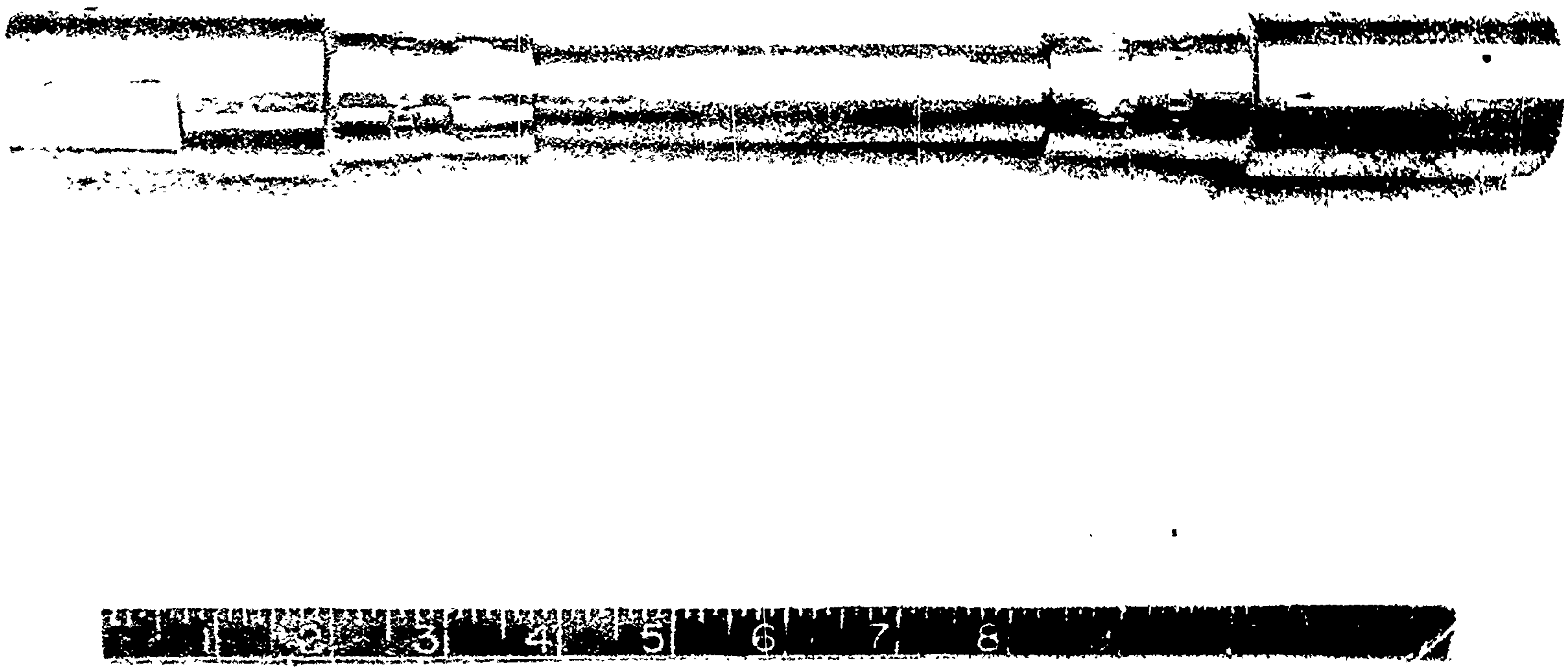


FIGURE 28: DEUTSCH PERMASWAGE FITTING FAILURE

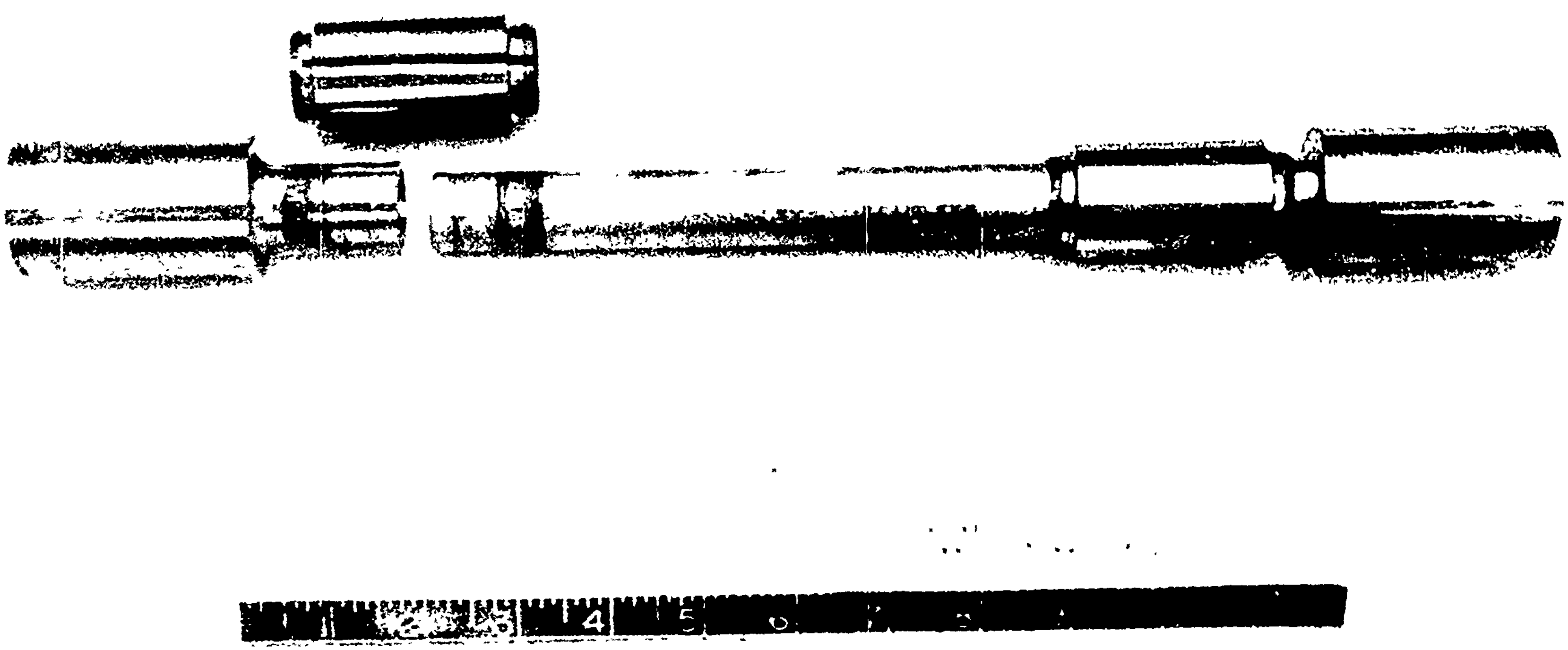


FIGURE 29: RAYCHEM CRYOFIT FITTING FAILURE

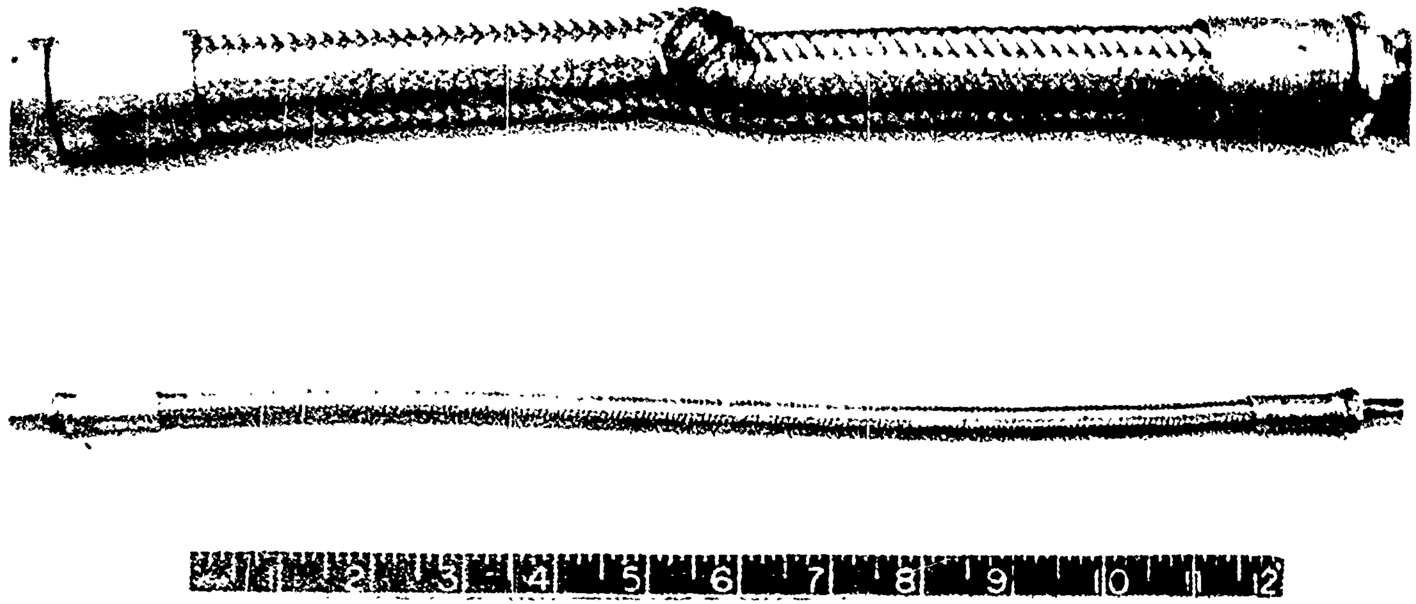


FIGURE 30: TITEFLEX HOSE FAILURE

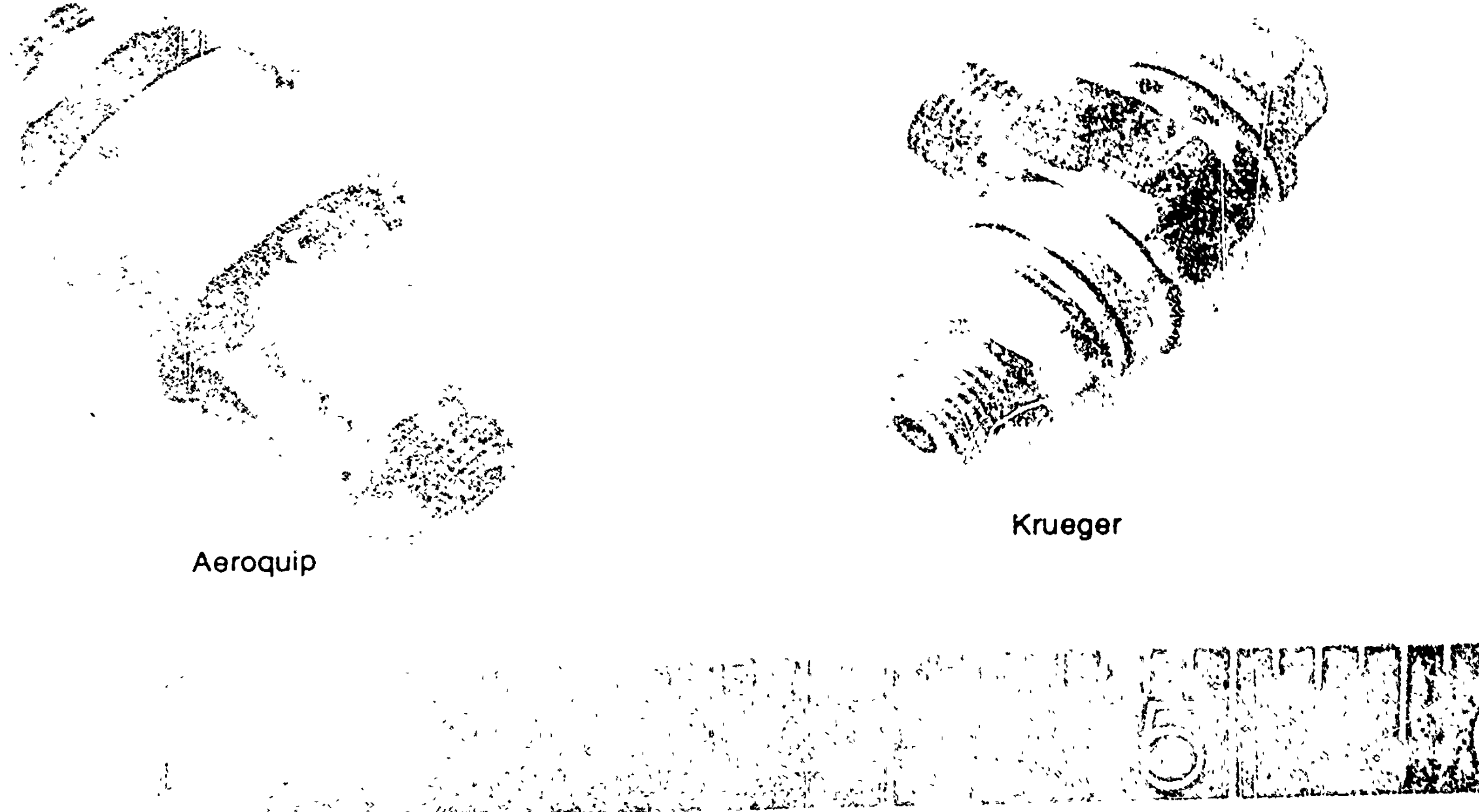
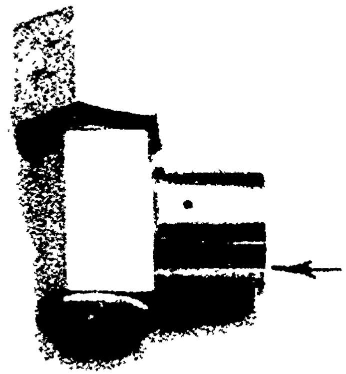


FIGURE 31: AEROQUIP AND KRUEGER SWIVEL FAILURE



SCREENING TEST - 8000 PSIG DISTRIBUTION SYSTEM

SINE WAVE IMPULSE PRESSURE TEST

SPECIMEN P.N S.N	WAVE PRESSURE PEAK PR	VALLEY PR	REMARKS
E-DE 03[illegible]	[illegible]4,000	2,800	CRACK IN SWIVEL BODY AT BOTTOM SURFACE OF AMINCO BOSS - FAILED AFTER 236,149 CYCLES

FIGURE 32: DEUTSCH SWIVEL FAILURE

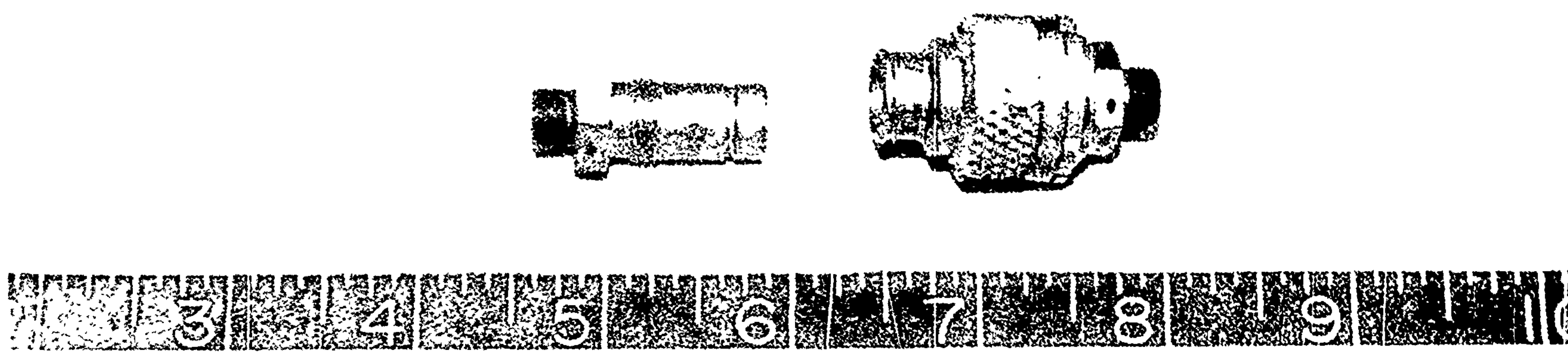


FIGURE 33: SYMETRIC QUICK DISCONNECT FAILURE

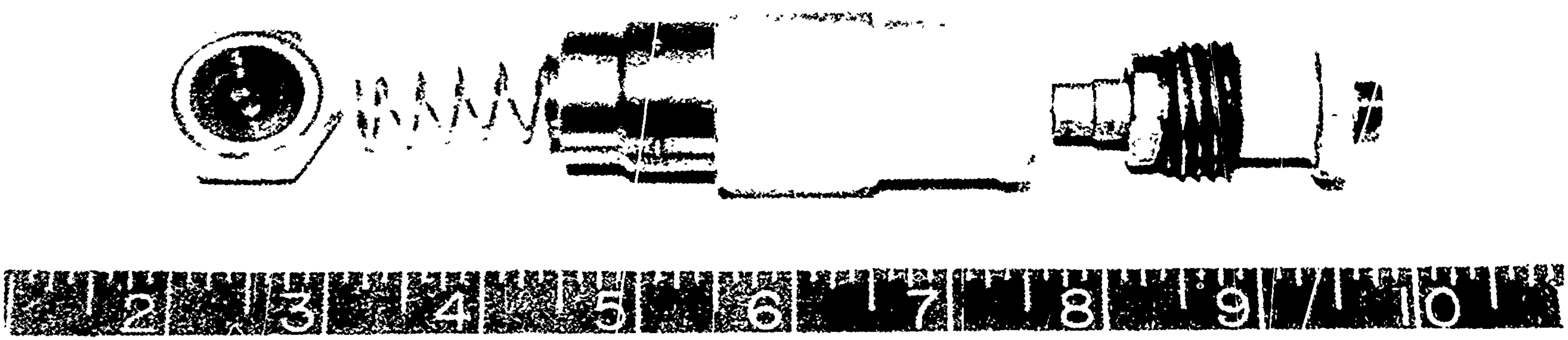


FIGURE 34: SEATON-WILSON QUICK DISCONNECT FAILURE

Vibration flexure in the 3/16-inch and 15/16-inch permanent and detachable fitting resulted in premature early failure when tested at a stress level of 20,000 psi. The scope of the program and schedule did not allow for further vibration testing. The following paragraphs informally summarize the hydraulic tube flex screening test results.

3.3.1 RAYCHEM CRYOFIT (15/16-INCH DIAMETER TUBE)

Unable to attain target level stress of 19,990. Highest level attainable at strain gages was 9,761. "B" end joint heated up at outboard interface and began extruding black (Teflon) material. Resonant frequency was 592 Hz; minimal cycles.

3.3.2 RAYCHEM CRYOFIT (3/16-INCH DIAMETER TUBE)

Attained 19,900 target stress and dwelled 142.5 minutes until failure. "B" end joint failed and began leaking at outboard interface. Frequency during most of the test was 575 Hz; total cycles = 4,916,250.

3.3.3 DEUTSCH (15/16-INCH DIAMETER TUBE)

Attained 19,990 target stress level and started tape. Level started dropping off immediately and was not able to tune in again. The tube started leaking and the test was shut down at 45 seconds duration. Failure was extensive cracking at "A" end outer swage marks. Frequency was approximately 575 Hz; approximately 25,000 cycles.

3.3.4 TELEDYNE-LINAIR (3/16-INCH DIAMETER TUBE)

Highest level of stress attained was 19,200, short of the 19,900, which was not attained because of leakage which began at inboard interface minimal cycles.

3.3.5 RESISTOFLEX (3/16-INCH DIAMETER TUBE)

Attained 19,990 target stress at 825 Hz, but level started dropping off immediately and test was halted at 366 seconds when leakage occurred at inboard sleeve of joint at "A" end; 301,950 cycles.

3.3.6 RESISTOFLEX (15/16-INCH DIAMETER TUBE)

Attained 19,990 target stress at 592 Hz and ran for 63 seconds when leakage occurred at "B" end interface at fitting; 37,000 cycles.

4.0 DISTRIBUTION SYSTEM DEMONSTRATOR

A distribution system demonstrator (Figures 35 and 36) was designed to subject hydraulic system components to the installation environment expected in advanced fighter aircraft. The demonstrator operation provides the capability to simulate structural vibration, structural flexure, pressure oscillations (representative of pump pressure ripple), system pressure surges, and thermal environment effects. Thus, a wide variety of complex interacting environments representative of those encountered in actual air vehicle operation is modeled with the demonstrator.

The demonstrator allows the design of optimum hydraulic systems. Components for the demonstrator are selected at their maximum effectiveness through S-N characteristic curves developed for each component by data collected from screening tests. Demonstrator test results also are added to the data base and are used in future test programs, comparison studies, and improvement assessments to existing components.

The objective of the endurance tests on the demonstrator was to demonstrate 8,000 psi hydraulic system components capabilities if withstanding the expected environment of advanced aircraft environments and simulate 2500 flight hours which is equivalent to 125 hours of testing when subjected to the test condition shown in Table IX. This objective was accomplished by:

1. Demonstrating that permanent joint-type titanium plumbing hardware could be installed "in place" in a demonstrator under conditions which duplicate many of the installation problems encountered in an actual air vehicle.

2. Assembling the test bed to serve for the evaluation and placement of detachable and boss fittings in inaccessible places which relate to reliability and maintainability problems.

3. Demonstrating hose assembly credibility adjacent to high-pressure maximum power distribution devices.

4. Subjecting the hydraulic plumbing system components/hardware, selected during the screening test phase, to a wide variety of environmental conditions representative of those encountered in actual aircraft operation.

5. Demonstrating that sufficient test data accumulated within the endurance limit properties of tubing and fittings so that the endurance limit of the plumbing demonstrator can be accurately predicted in the presence of complex environmental input.

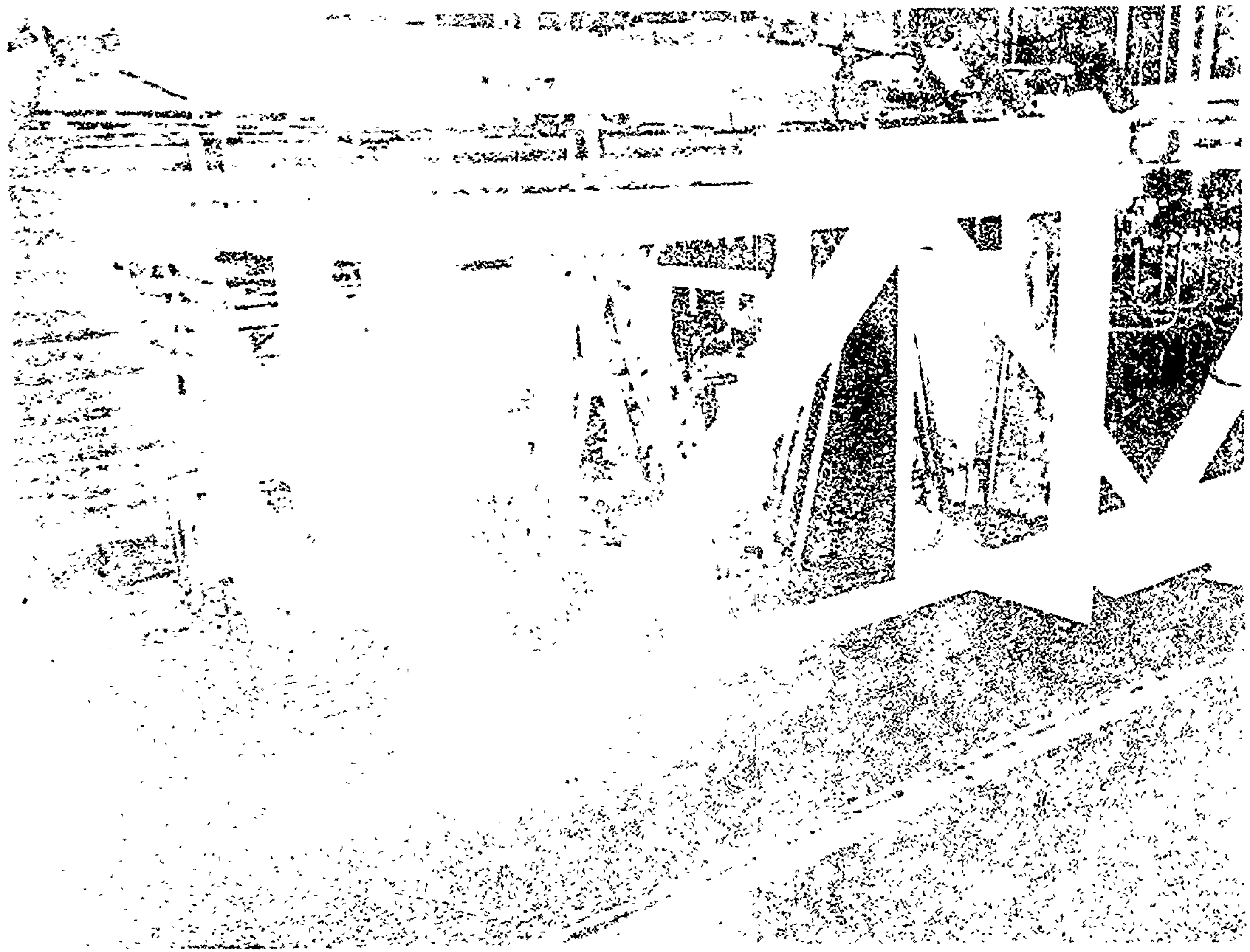


FIGURE 35: DEMONSTRATOR TUBING INSTALLATION

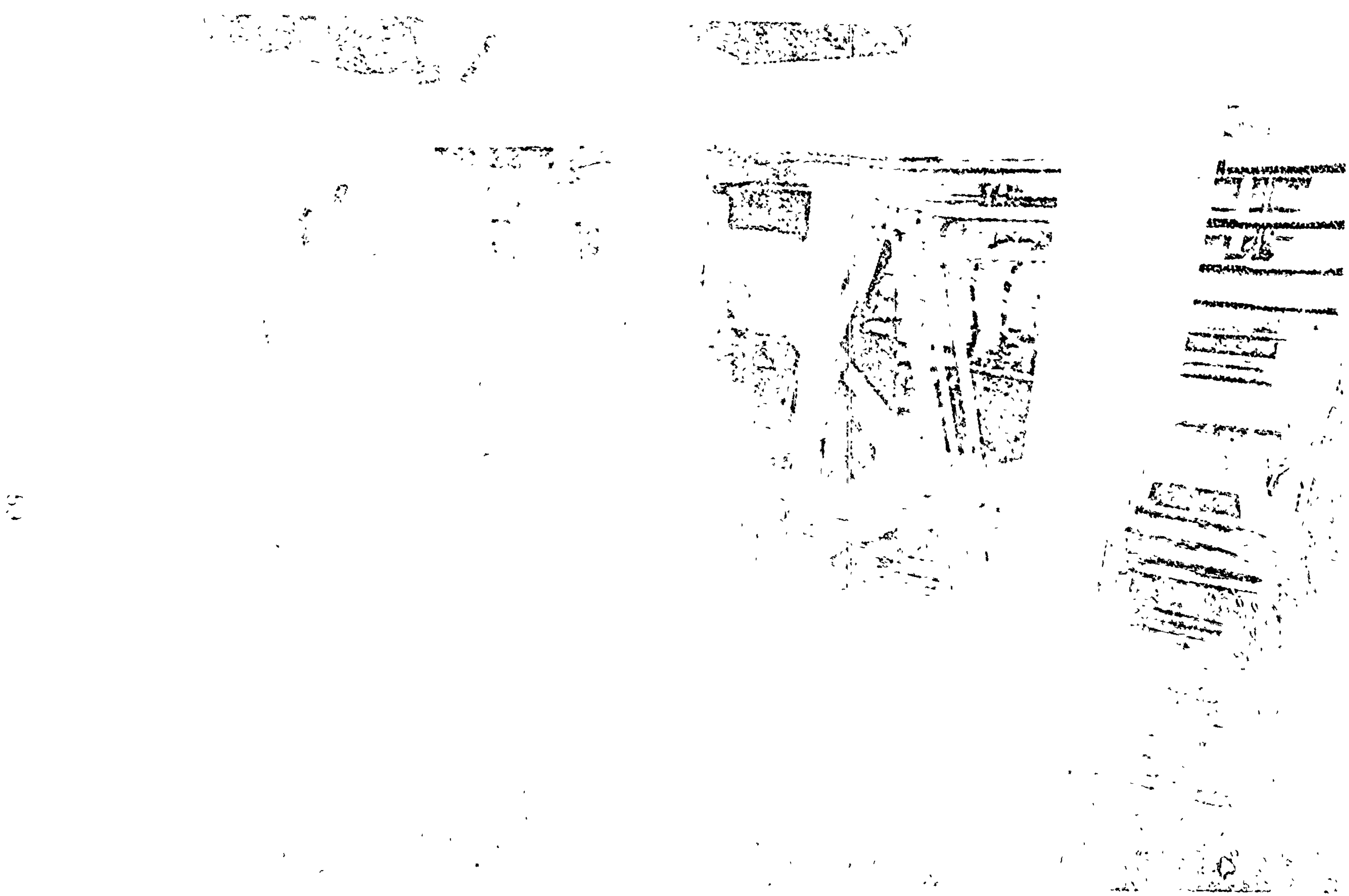


FIGURE 36   DEMONSTRATOR COMPONENT INSTALLATION

TABLE IX
DEMONSTRATOR TEST CONDITIONS

Test Title	Number of Test/Hrs	Fluid & Ambient Temperature (^oF)	System Pressure	Special Items
Pump Pressure Pulsation	125 Hrs	Fluid -65 to 400^{o}F Ambient -65 to 500^{o}F	8000 psig (mean pressure)	400 psig peak-to-peak pulsations
Structural Flexure	125 Hrs	Fluid -65 to 400^{o}F Ambient -65 to 500^{o}F	8000 psig	Bulkhead flexure frequency 30 cpm at no failure strain level 305,000 total cycles
Structural Vibration	125 Hrs	Fluid -65 to 400^{o}F Ambient -65 to 500^{o}F	8000 psig	Vibratory acceleration + 2 g at 240 cps
System Pressure Oscillation	125 Hrs	Fluid -65 to 400^{o}F Ambient -65 to 500^{o}F	8000 psig (mean pressure)	Impulse oscillation 0-1500 psig; sinusoidal oscillation 40,000 psig at 30 cmp; sinusoidal oscillation 4,000 - 9,200 psig (375,000 cycles at 60 cpm) performed inter-mittently
Thermal Gradient	125 Hrs	Fluid -65 to 400^{o}F Ambient -65 to 500^{o}F	8000 psig	Temperature cycles, -65 to 500^{o}F; 5 cycles, room temperature to 500^{o}F; 45 cycles

The tesis planned for the distribution system demonstrator were divided into two major categories, namely, "calibration tests" and "endurance tests."

A summary of the 125-hour endurance test is discussed in detail in para. 4.3. Of the 210 components tested during the endurance test, seven component failures occurred and they are discussed in para.4.3 and Appendix E.

4.1 DEMONSTRATOR DESIGN

The design of the demonstrator frame is shown in Figure 37. The basic demonstrator frame was mounted on a movable cart as shown in Figure 35. The demonstrator was tested in a variable temperature chamber at a temperature range of -65 to +400°F. The demonstrator was attached to a hydraulic service system including reservoir, hydraulic power unit and filters. An attachment link to a vibration machine was provided through the temperature chamber walls. The demonstrator was attached to a hydraulic test system capable of generating sinusoidal pressure waves. Instrumentation was provided at all critical points. Instrumentation monitored stress, "g" loading, temperature (ambient, tubing and fluid), structural deflections, and fluid pressures.

Calibration tests were performed in accordance with Table X prior to the demonstrator endurance test.

The demonstrator includes as a minimum the 350 feet of tubing; 50 feet each of seven sizes (3/16-inch through 15/16-inch), 5 detachable fittings, 10 permanent fittings, 2 boss fittings, hose, swivel, and quick disconnect (shown in Figure 38). Design studies/reviews were conducted to ensure adequate demonstration of pertinent plumbing problems and the selection of critical stress points for location of instrumentation.

The tubing was routed in the demonstrator as shown in Figure 34. The tubing was bent to 3-D bend radius using Rockwell Specification ST0102LA0008 as a guide. The tubing was instrumented with strain gages to monitor critical stress points as shown in Figure 39. Permanent and detachable fittings were installed on the tubing prior to installation into the demonstrator. Tubing supports were of a design configuration that will prevent damaging resonance vibration and will allow structural flexing. Other test hardware (hoses, swivel and quick disconnects) was installed in the demonstrator free of any binding and excessive preload.

A computer study of the tube configuration was undertaken to more accurately determine the total stress within the Z tube routing (Figure 40) which forms the structural flexure portion of the demonstrator. The objective of the study was to generate stress data on the Z tube configuration so that each tube size would be subjected to the same maximum total stress during flexure.

Because of the curvilinear motion at the attachment points on the flexure bulkhead, both bending shear and axial loads are applied to the tubing at these bulkhead constraints. A typical load application for all seven tube sizes is shown in Figure 41. The vertical distances between the upper and lower support points (end of the Z tube) for each tube size were altered in order to obtain maximum and uniform stresses at similar

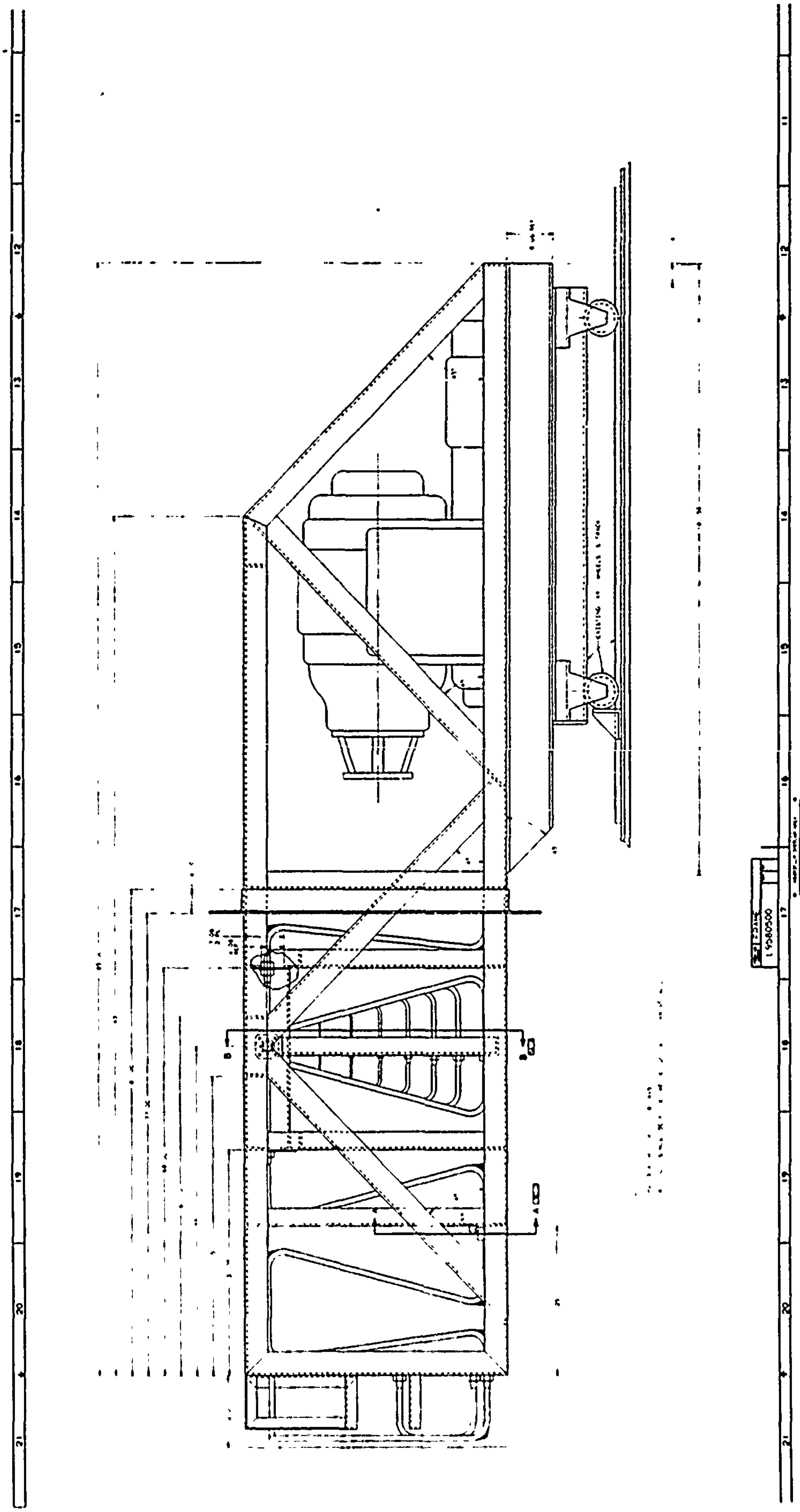
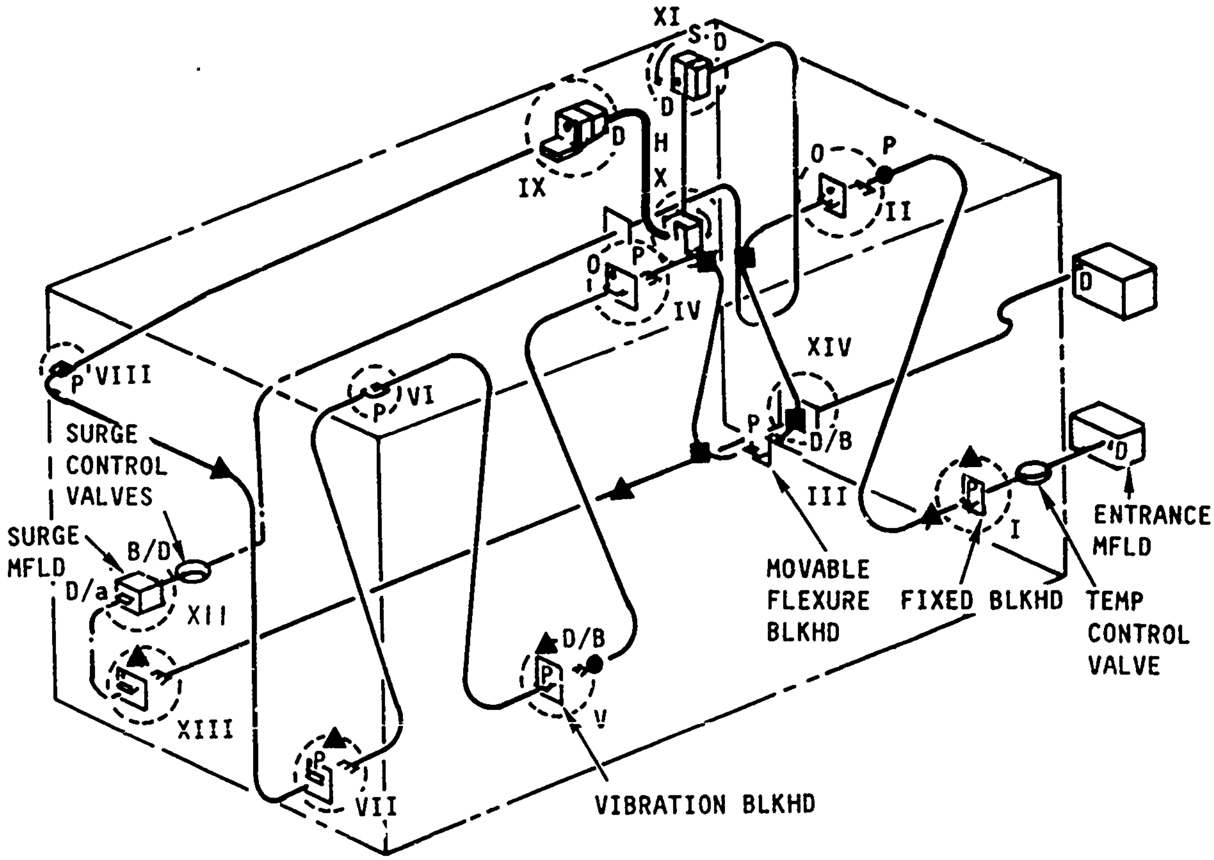


FIGURE 37: DEMONSTRATOR FRAME DESIGN

TABLE X
CALIBRATION TESTS

	Test Title	Number of Tests/Hours	Fluid & Ambient (Temperature (°F)	System Pressure	Special Items
CALIBRATION TESTS	Pump Pressure Pulsation	1	100 ± 60	8000 + 220 psig - 0	System discharge flow rate 1-3 gpm, 400 psig peak-to-peak pulsations
	Structural Flexure	1	100 + 60 - 30	8000 ± 200 psig	Bulkhead flexure frequency 30 cpm at no failure strain level
	Structural Vibration	1	100 ± 60	8000 - 200 psig	Vibratory acceleration ± 2 g at 24 cps
	System Pressure Oscillation	1	100 + 60 - 30	8000 ± 200 psig	Impulse oscillation 0 - 1500 psig, sinusoidal oscillation 4000 psig at 30 cpm and 9200 psig at 60 cpm, system discharge flow rate 0 gpm
	Thermal Gradient	1	See special items	8000 ± 200 psig	Discharge flow rate 4-12 gpm, fluid temperature -65°F to +400°F, ambient temperature -65°F to + 500°F



LEGEND		
P	-	PERMANENT FTG
D	-	DETACHABLE FTG
B	-	BOSS
H	-	HOSE
S	-	SWIVEL
Q/D	-	QUICK DISCONNECT
▲	-	THERMOCOUPLE
●	-	BENDING & TORSION STRAIN GAGE
■	-	HOOP STRESS STRAIN GAGE

HARDWARE TYPE	TEST ZONES														
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	TOTAL
PERM	1	1	1	1	1	1	1	1	-	-	-	-	1	1	10
DET	1	1	1	1	1	-	-		1	1	2	2	1	-	13
BOSS	-	-	1	-	1	-	-	-	1	-	-	2	-	-	4
HOSE	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
SWIVEL	-	-	-	-	-	-	-	-	-	1	1	-	-	-	2
QD	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1

NOTE: THE LINE ROUTING WILL BE DUPLICATED SEVEN TIMES IN THE ACTUAL DEMONSTRATOR; THE STRAIN GAGES WILL BE DUPLICATED AT APPROPRIATE LOCATIONS.

FIGURE 38: CONCEPTUAL VIEW OF THE DEMONSTRATOR

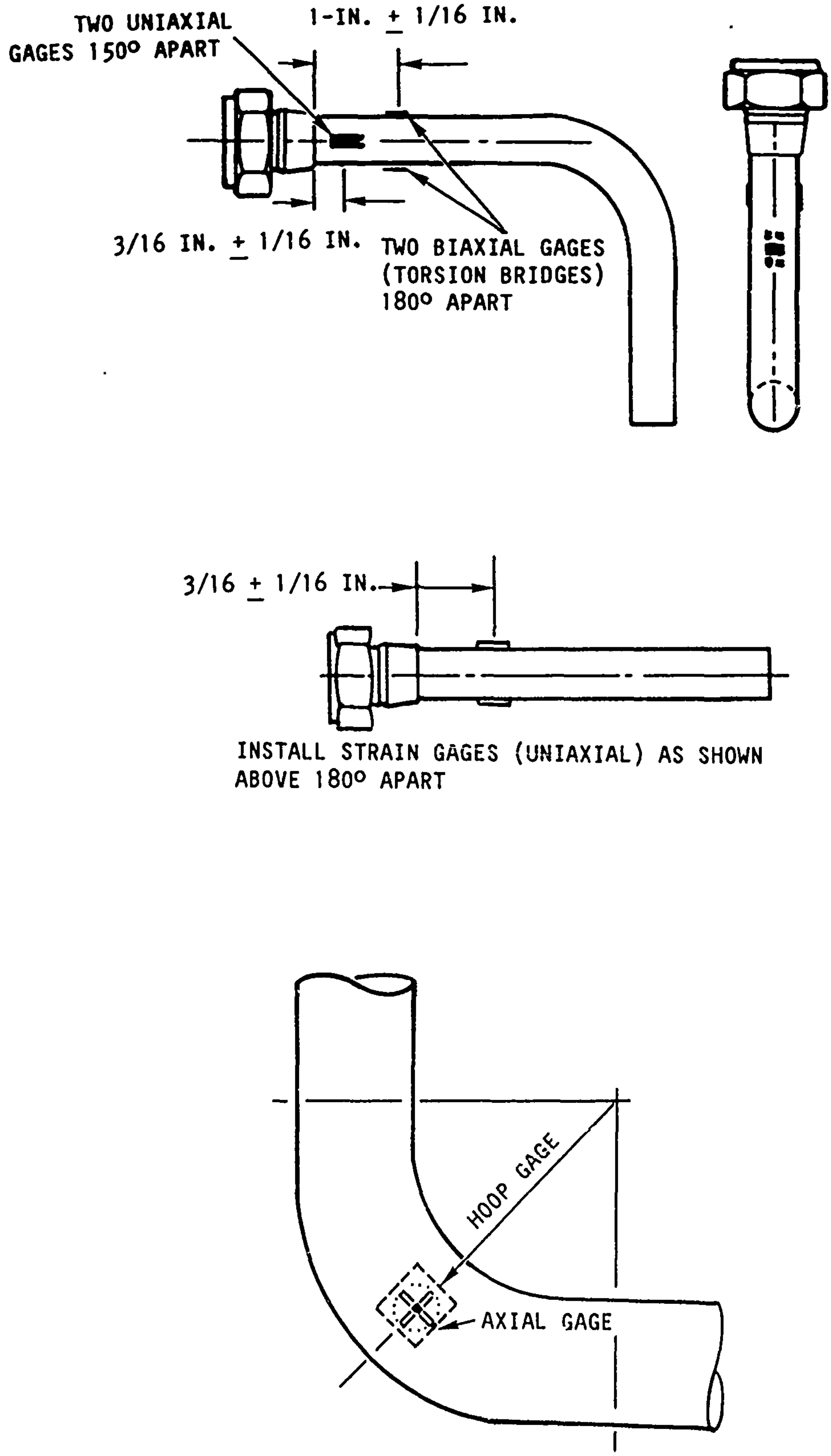
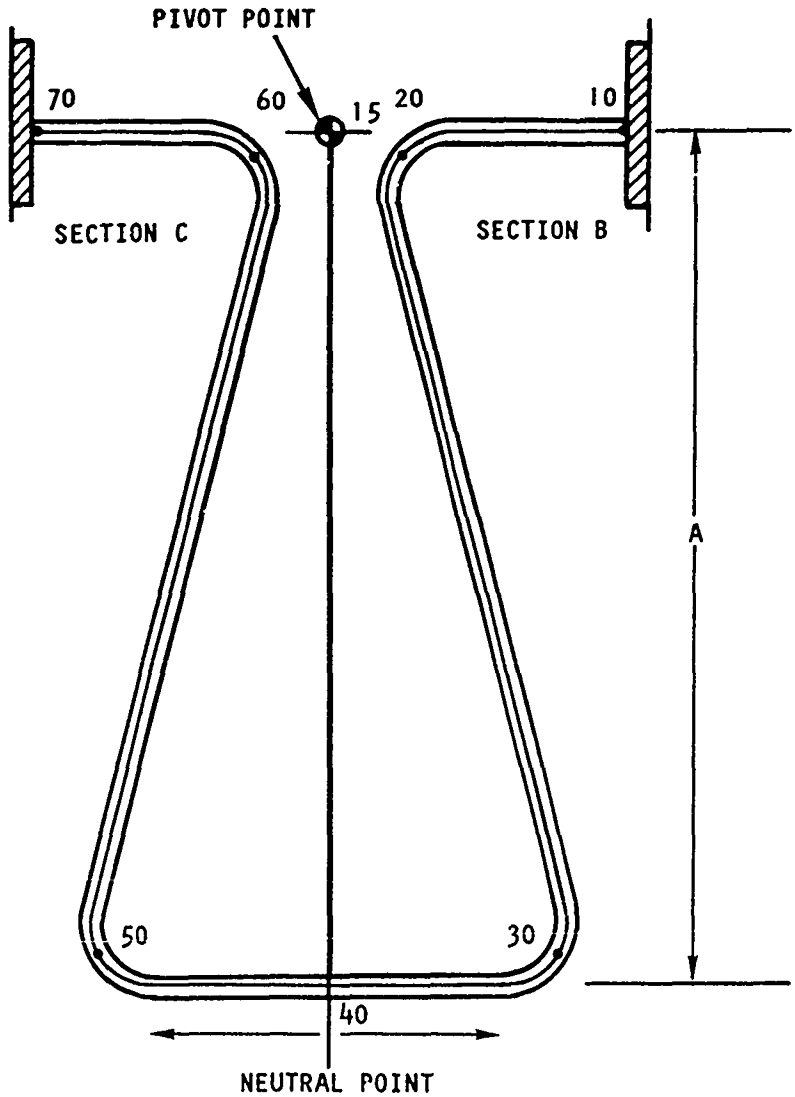


FIGURE 39: TUBE INSTRUMENTATION



TUBE SIZE DIA.	DIA A INCHES	STRESS, PSI						
		SECTION B			NEUTRAL	SECTION C		
		PT 10	PT 20	PT 30	PT 40	PT 50	PT 60	PT 70
.1875	9.25	4,392	17,050	15,302	2,197	13,514	16,026	3,294
.3125	14.75	2,774	17,011	14,128	1,139	11,981	15,422	1,860
.4375	19.85	1,007	17,048	13,270	3,612	11,003	15,206	26
.5626	24.66	964	17,067	12,560	6,207	10,077	14,931	1,981
.6875	29.30	3,110	17,014	11,894	8,894	9,141	14,554	4,103
.8125	33.50	5,281	17,072	11,393	11,571	8,521	10,780	6,240
.9375	38.33	7,736	17,047	10,974	14,333	7,879	14,212	8,597

NOTE: ANALYSIS BASED ON AN ANGULAR ROTATION OF BULKHEAD ± 0.026 RADIANS (1.5°)

FIGURE 40: Z-TUBE COMPUTER STRESS ANALYSIS

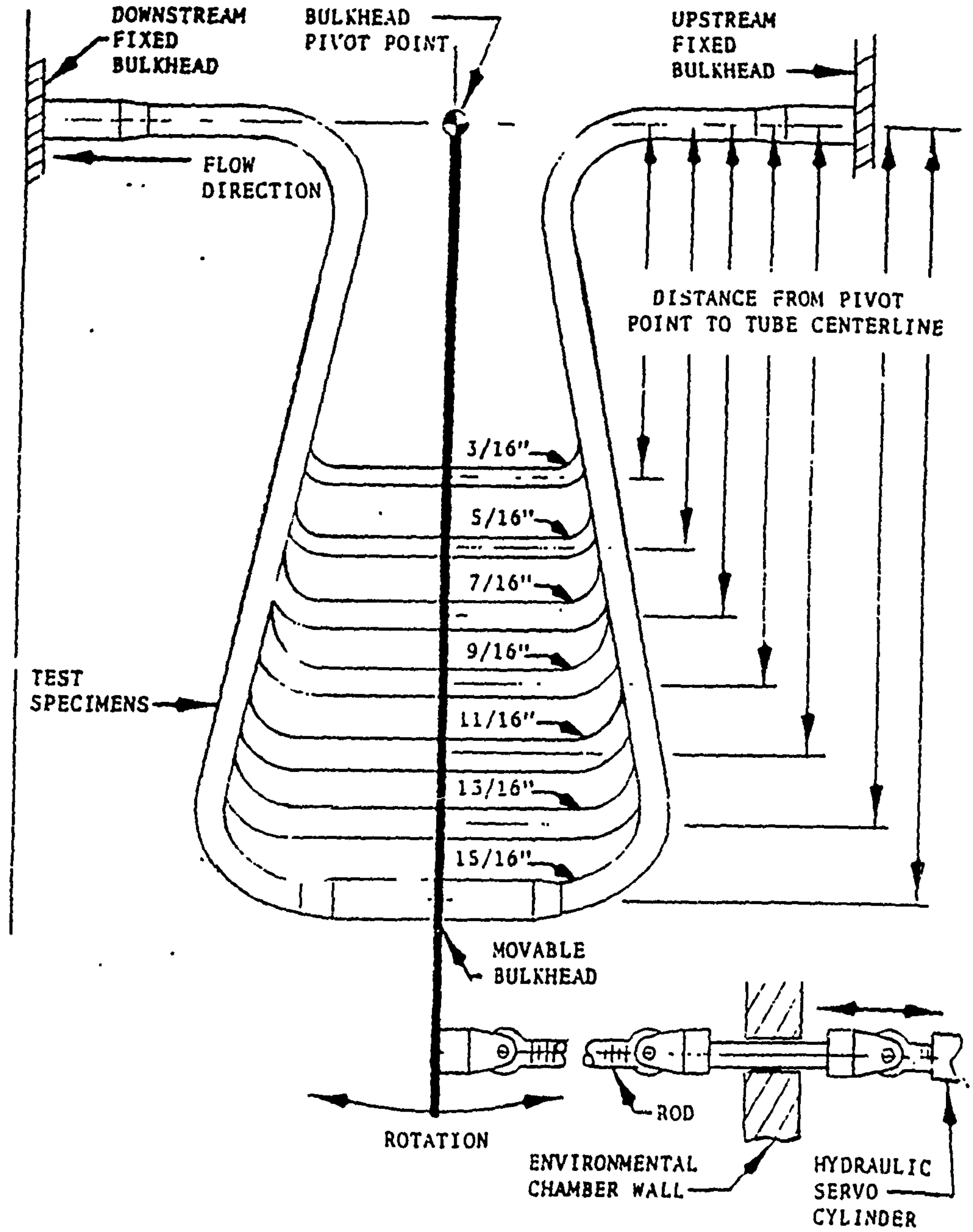


FIGURE 41: Z-TUBE LOADING APPLICATION

locations for each tube size. Stresses along the Z tube routing were determined using the computer program PIPELINE. The PIPELINE program was generated by McDonnell Douglas Automation. PIPELINE was selected for this analysis because of extensive previous use by Rockwell and excellent correlation between analytical results and test results. The results of this computer prcgram are included as Appendix C. Strain gages will be located on each tube assembly to monitor the stress loading in the tube.

4.1.1 LINE SUPPORT

Line supports for all line sizes were supplied by TA Manufacturing at no cost to the program. Drawings of the various support configurations are shown in Appendix D.

4.2 HARDWARE SELECTION

Hardware to be tested on the demonstrator was selected based on its performance during the screening test phase. Due to the overall satisfactory performance of the hardware tested, a primary and alternate selection was available for each design configuration shown in Table XI except for hose assemblies and fittings. Titeflex was the only hose supplier that supplied hoses in all sizes. Rexnord-Rosan was the only boss fitting supplier. The primary test hardware will be subjected to all applicable demonstrator endurance tests.

The fluid used in the performance of all demonstrator tests was MIL-H-83282. The test fluid controlled in accordance with or equivalent to LQ0505-201.

4.3 ENDURANCE TEST

During the endurance test a total of 134.5 hours of testing was completed. While most of the test objectives were met, some were not. Table XII gives a summary of the test results. No failures were encountered in the permanent, detachable and boss fittings. However, seal failures occurred in the 3/16 inch quick disconnect supplied by Seaton-Wilson and Symetrics (Figures 42 and 43) and the 3/16 inch swivel assemblies supplied by Krueger (Figure 44). Hose assembly failures occurred in hoses supplied by Titeflex (Figures 45 and 46). See Table XIII.

Failure analysis was conducted by the suppliers. Based upon data supplied by the suppliers the failure of the various components was caused by high temperature exposure. This resulted in the component not performing as designed. Failure reoorts that were generated by the suppliers are listed in Appendix E.

TABLE XI
TEST HARDWARE SELECTION

TEST HARDWARE	SUPPLIER	COMMENTS
Detachable Fittings	* AEROQUIP-LINAIR Aerofit Products Airdrome Parts	The performance of the 15/16 - Inch Aeroquip Linair detachable fitting showed a substantial improvement after three (3) modifications
Permanent Fittings	*DEUTSCH METAL PARTS Raychem	The Deutsch Permaswage fitting was subjected to one (1) modification
Boss Fittings	*REXNORD-ROSAN	No modification was required
Hose Assemblies	*TITEFLEX	The hose connection was improved based on test results obtained during the impulse correlation tests
Swivel Assemblies	*AEROQUIP Deutsch R. E. Krueger	High temperature seal designs are being considered by all suppliers
Quick Disconnects	*SYMETRICS Aeroquip Seaton-Wilson	One (1) Design modification was made to quick disconnects made by Symetrics and Seaton-Wilson.

* Primary demonstrator test hardware

TABLE XII
125-HOUR ENDURANCE TEST SUMMARY

HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM

ITEM	REQUIREMENT	ACTUAL
TEST TIME, Hrs.	125	134.5
MECHANICAL FLEX, Cy	305,000	432,000
HOSE/SWIVEL FLEX, Cy	44,955	44,955
VIBRATION, Cy	86,400,000	132,885,000
THERMAL CYCLES, Cy	18	18
THERMAL GRAD'NT, Cy	2	0
PUMP PULSATIONS, Cy	270,000,000	57,304,800
SINE WAVE IMPULSE, Cy	375,000	18-60,000

TABLE XIII
COMPONENT FAILURE SUMMARY

HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM

- **HARDWARE TESTED (210)**
  - 14 SWIVELS
  - 14 DISCONNECTS
  - 14 HOSES
  - 74 PERMANENT FITTINGS
  - 94 DETACHABLE FITTINGS

- **HARDWARE FAILURES (7)**
  - 3 DISCONNECT (SEATON - WILSON)
  - 3 DISCONNECT (SYMETRICS)
  - 3 SWIVEL (KRUEGER)
  - 3 HOSES (2) (TITEFLEX)
  - 5 HOSE (TITEFLEX)
  - 15 HOSE (TITEFLEX)

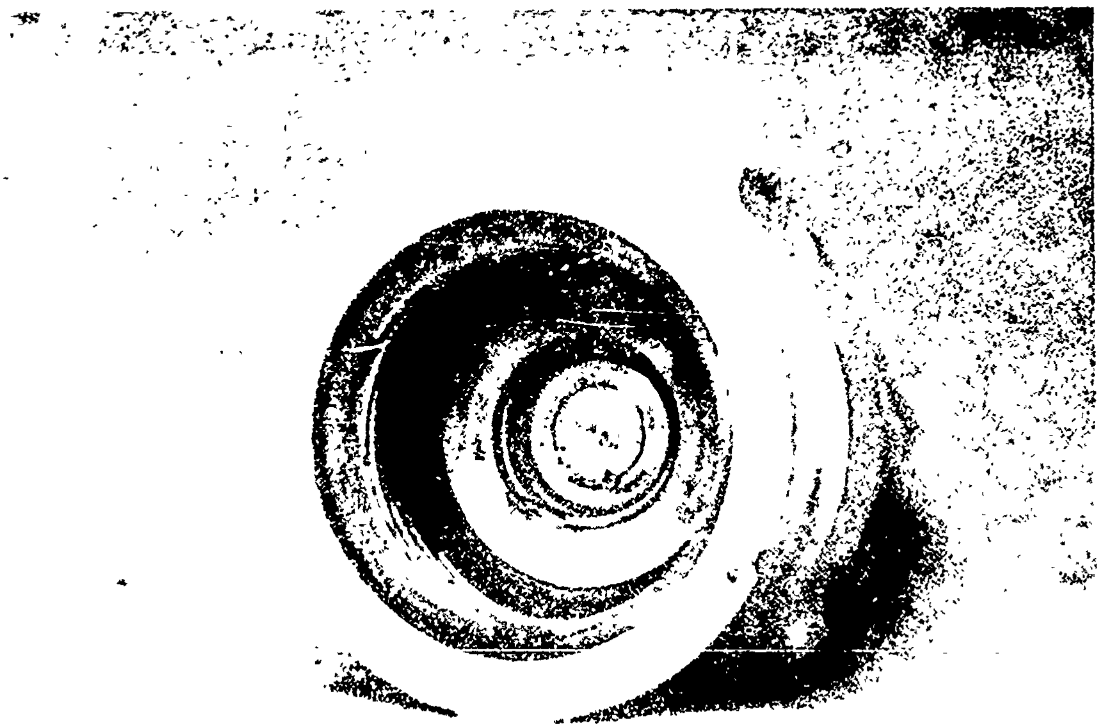


FIGURE 42 SEATON WILSON QUICK DISCONNECT FAILURE

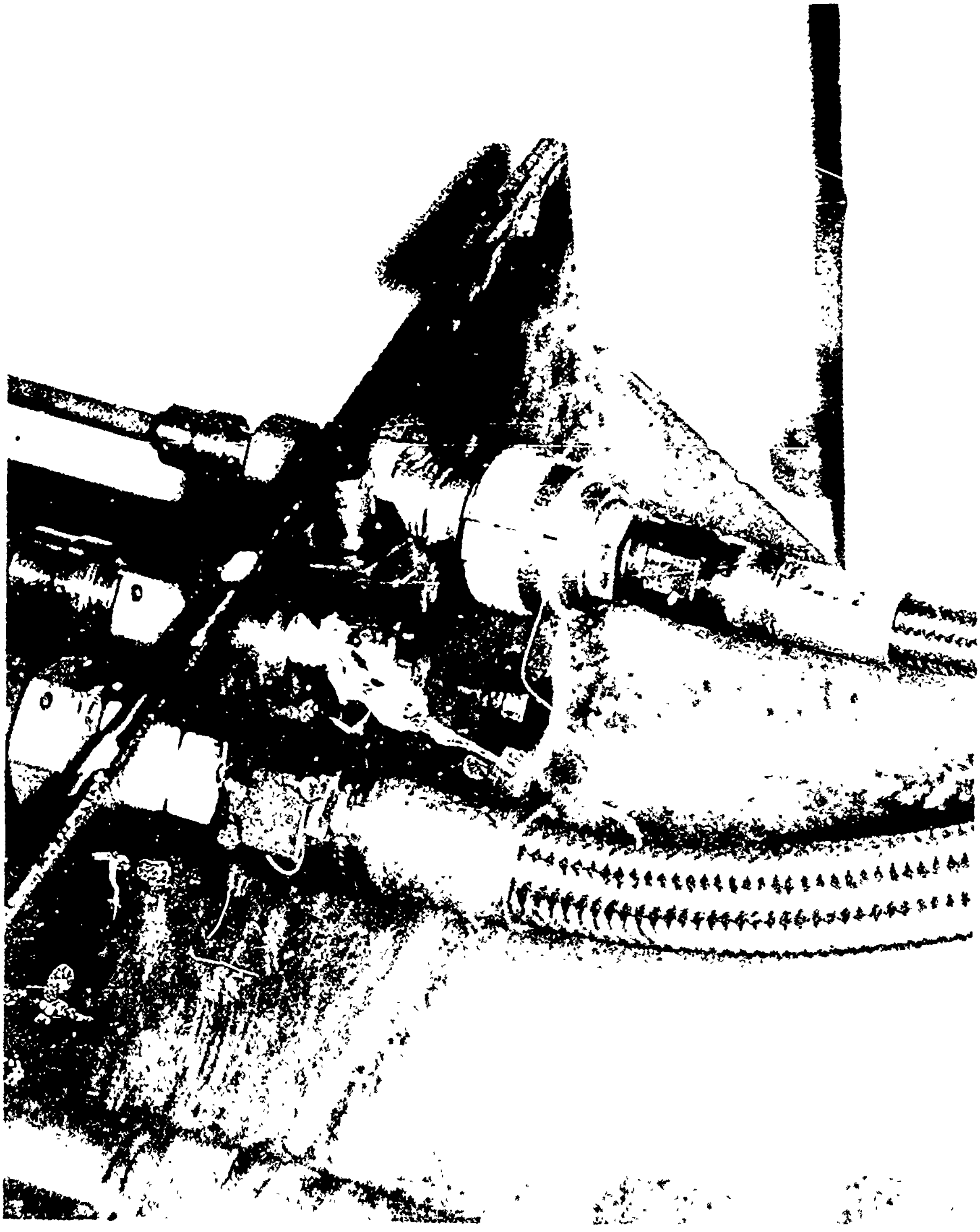


FIGURE 43: SYMETRIC QUICK DISCONNECT FAILURE

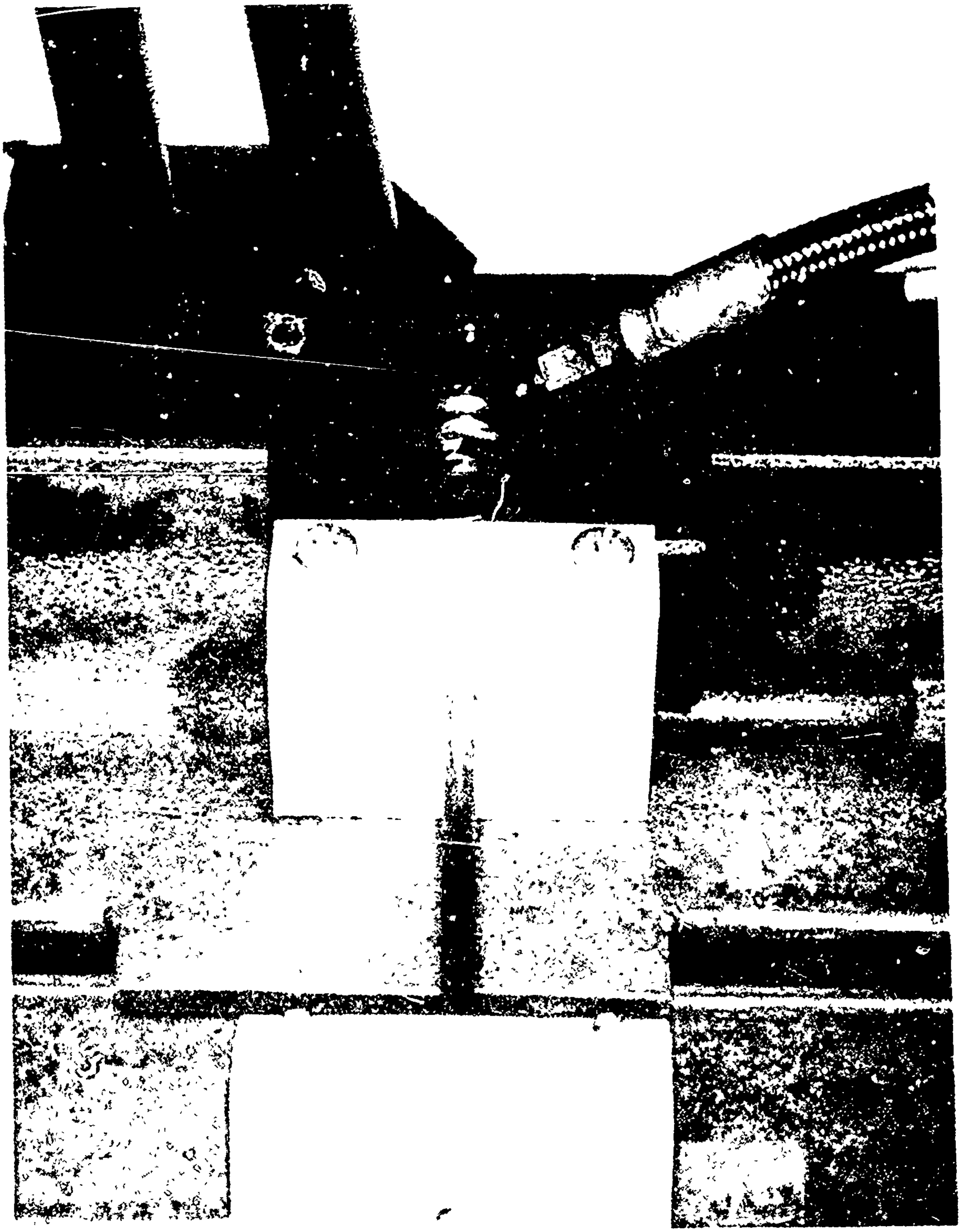


FIGURE 44: KRUEGER SWIVEL FAILURE

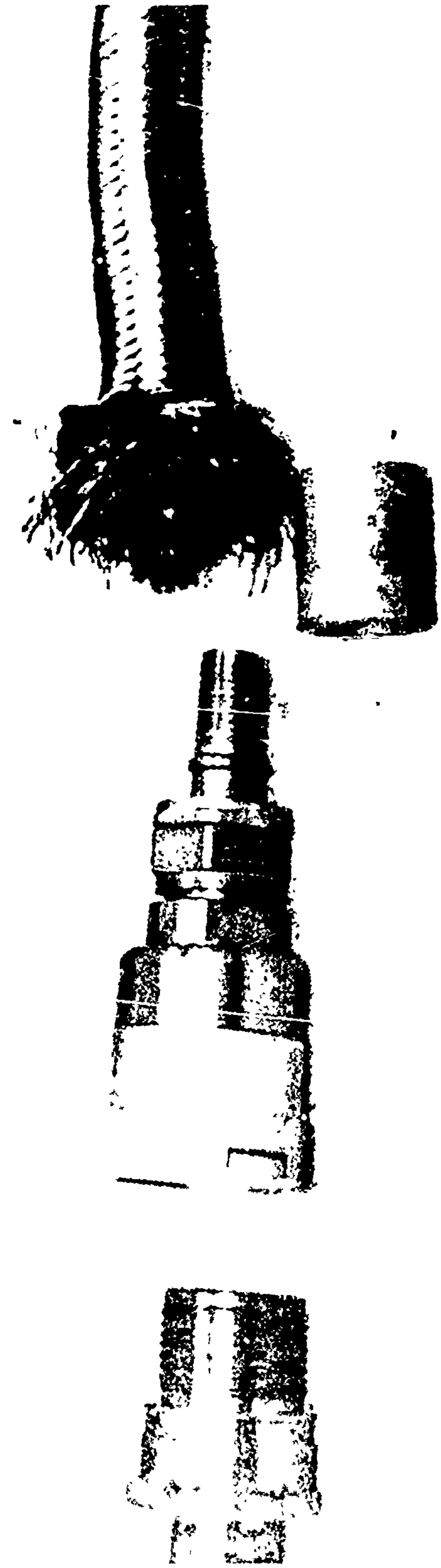


FIGURE 45: TITEFLEX 3/16-INCH HOSE FAILURE

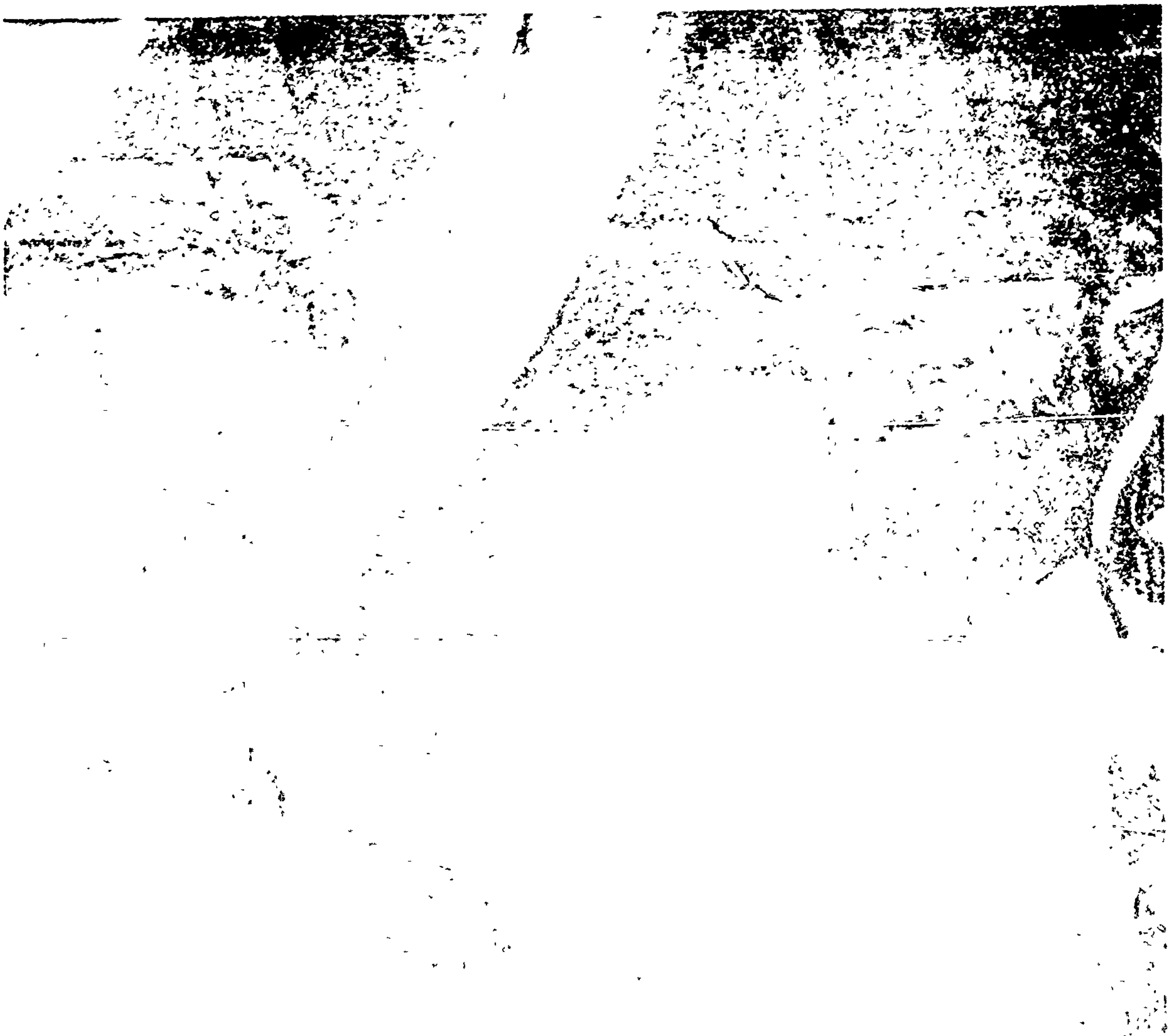


FIGURE 46 TITEFLEX 15/16-INCH HOSE FAILURE

4.3.1 PUMP PRESSURE PULSATIONS

Fluid pressure and flow was supplied to the demonstrator by test pump mounted on the fixed bulkhead. The test pump was capable of generating a fluid flow of at least 5 gpm at a pressure of 8000 psi with a pressure oscillations range of 150 to 400 psi peak to peak.

The test pump was capable of generating pressure pulsations of a frequency range of 220 to 705 cps. Vibratory response from individual pump ripple (Figure 47) was recorded by accelerometers.

As shown in Table XII, the required number of pump pressure pulsations was not achieved. While 270 million pump pulsations is the actual number expected in 125 hours of testing, it was found that the sine wave cycling could not be conducted concurrent with pump ripple. Analysis have shown that 50 million cycles insures infinite life. Thus the number of pump pulsation cycles was reduced to obtain a balance of sine wave cycles.

4.3.2 STRUCTURAL FLEXURE

Structural flexure was applied to test specimens through a movable bulkhead which rotates about a pivot point as shown in Figure 40. The structural flexure loading was representative of the aircraft environmental loading conditions shown in Figure 48 along with strain gage stress data shown in Figure 49.

The test specimens were mounted in such a manner that a uniform maximum stress was applied to all tube configurations. The Z tubes were instrumented with strain gages at the point of maximum stress (refer to Figure 40). The movable bulkhead was capable of generating equivalent stresses of 17,000 psi in the Z tubes assemblies at the specified point. The bulkhead traveled at frequencies up to 60 cpm. The Z tubes were tested at one representative stress level.

4.3.3 STRUCTURAL VIBRATION

Structural vibrations were applied to a movable bulkhead by a rod attached to a vibration exciter. The bulkhead was subjected to a vibratory acceleration of $\pm$2g's at 240 cps. Vibratory response was recorded by accelerometers (Figure 50) and vibratory induced stresses were recorded by strain gages.

4.3.4 THERMAL GRADIENT

The demonstrator was subjected to thermal stresses produced by temperature differentials between the support structure and tubing. The

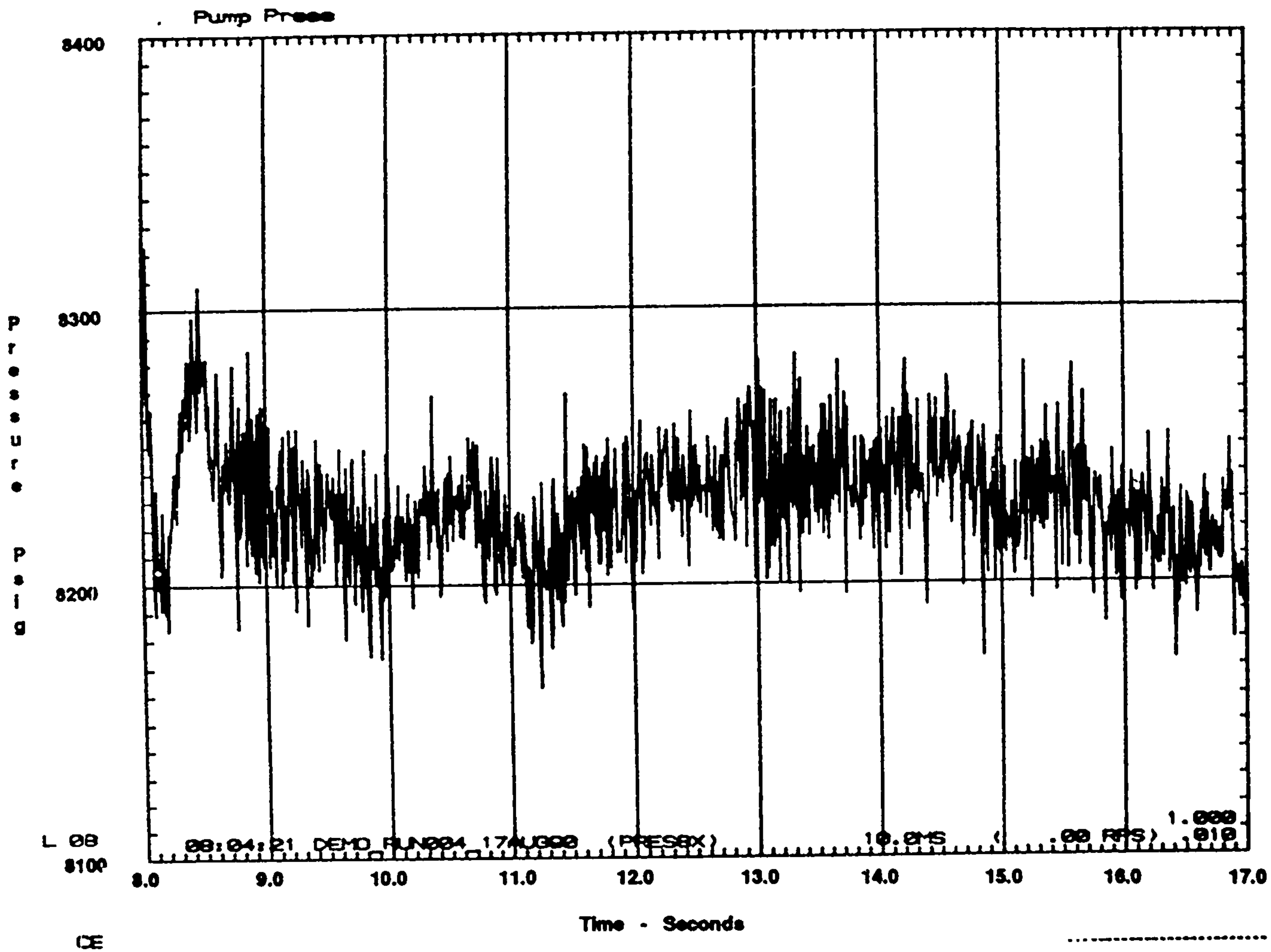


FIGURE 47: TYPICAL PUMP RIPPLES

MISSION PROFILE

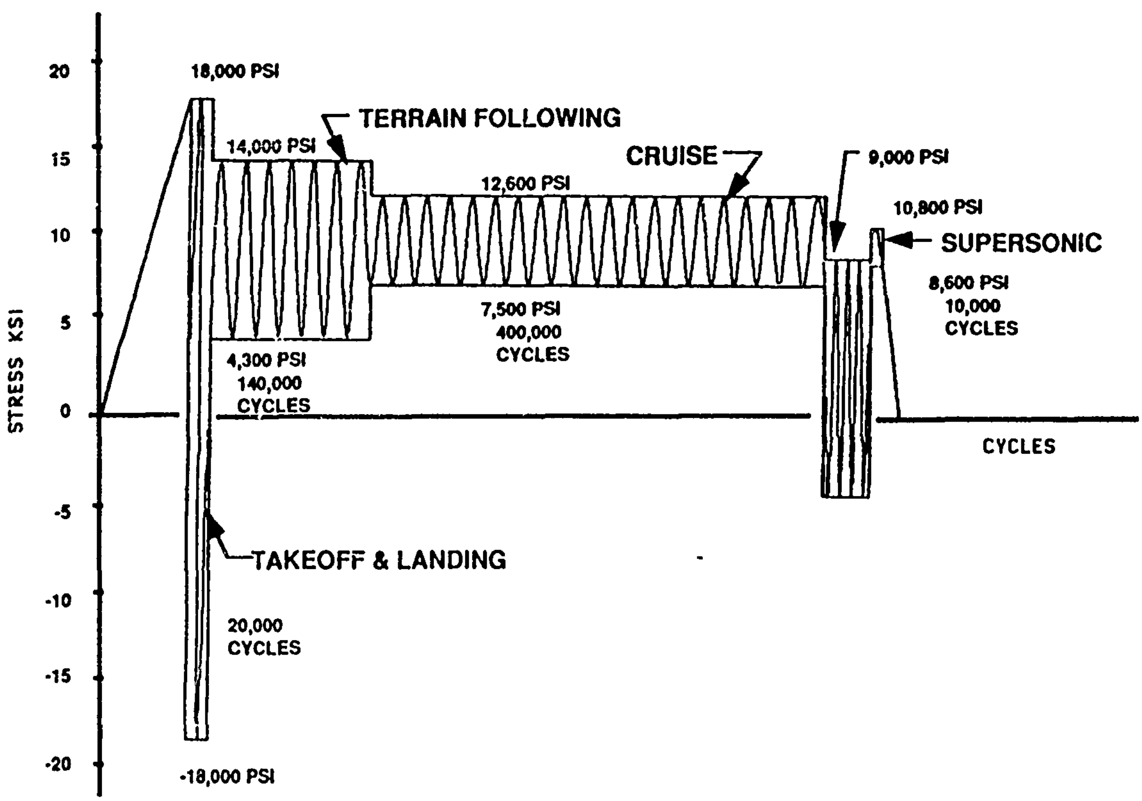


FIGURE 48: STRUCTURAL FLEXURE LOADING CONDITIONS

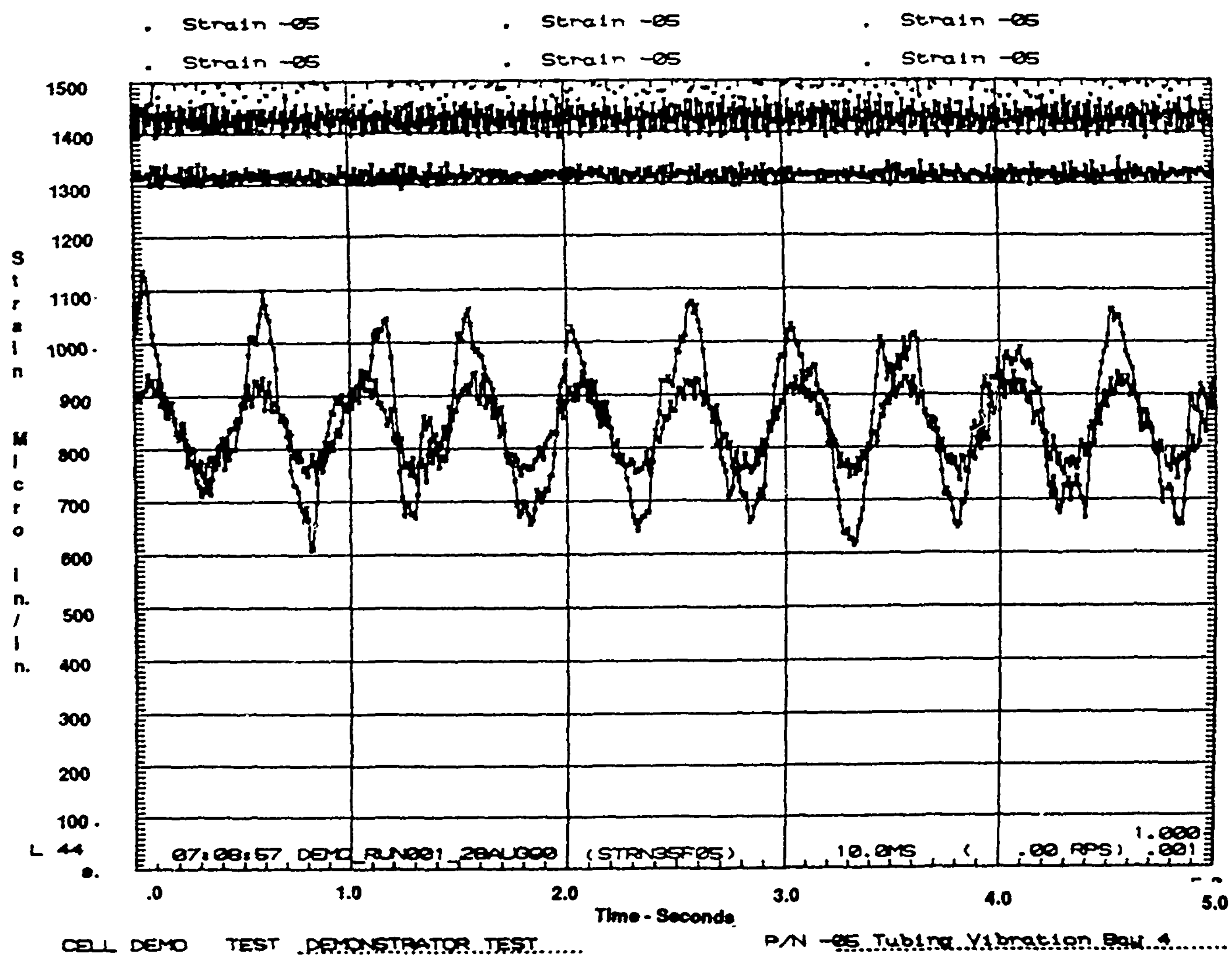


FIGURE 49: STRAIN GAGE OUTPUT

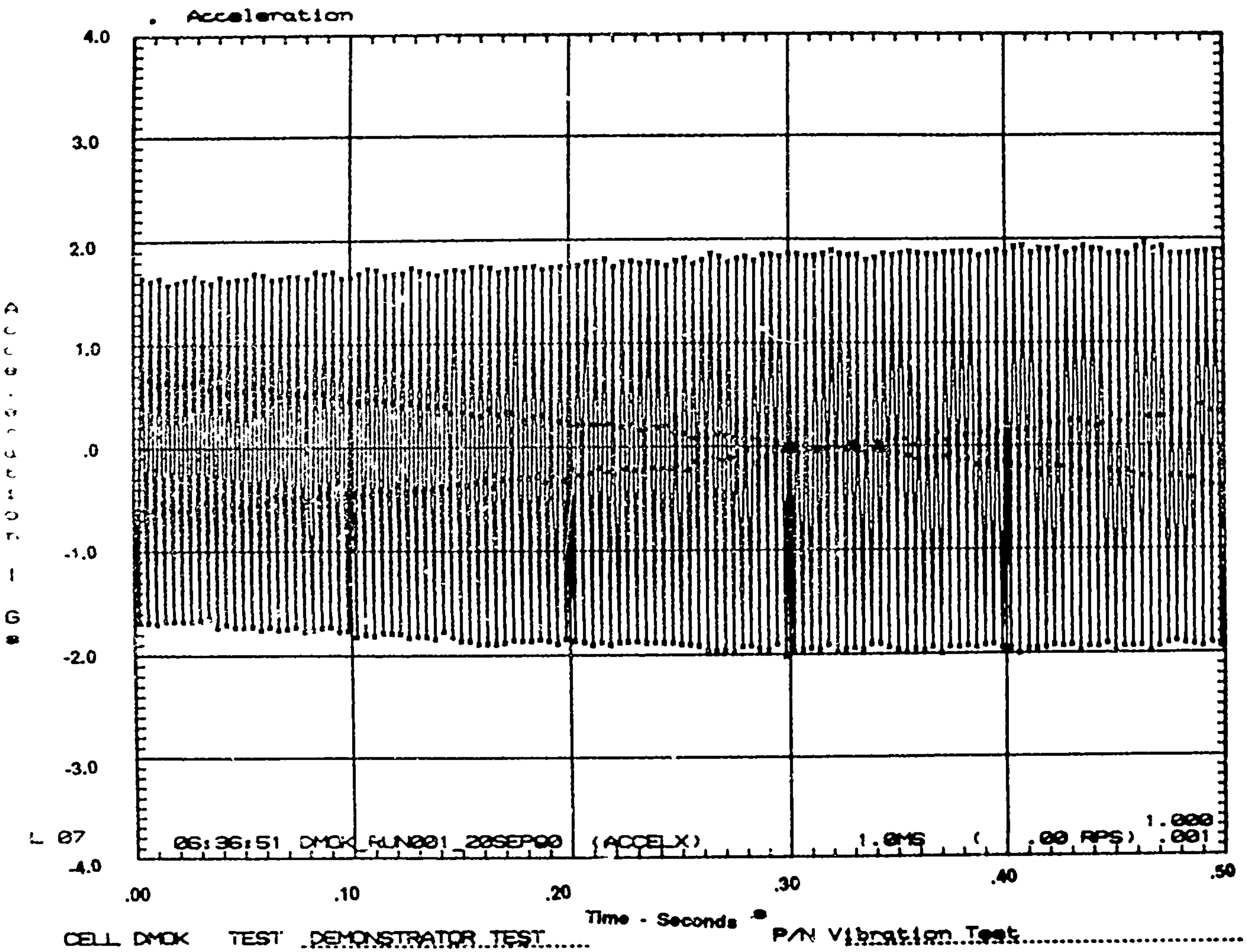


FIGURE 50: TYPICAL VIBRATION RESPONSE

fluid and ambient temperature was independently controlled. Thermal cycles are shown in Figure 51.

The thermal gradient tests could not be run because the high temperature pump failed and could not be repaired in time to support test completion before the end of the fiscal year.

4.3.5 PRESSURE OSCILLATIONS

The simulator was subjected to sinusoidal pressure oscillations (Figure 52) every other l0-minute period. A l0-minute dwell period was separate each pressure oscillation period. Sinusoidal oscillation was applied at an R-factor of 0.2 and a frequency of 4 Hz +/- 1.5 Hz. The oscillations was applied in a pressure level range of 2,100 psi .

As shown in Table XII, the required number of pressure oscillations could not be achieved within the program schedule. This was due to the fact that the demonstrator fluid volume was great enough to prevent obtaining full amplitude sine waves when the entire system was cycled. By dividing the volume into four approximately equal parts, the proper magnitude could be obtained. While this is a reduction in the demonstrator test objectives, the data base provided by the screening tests conducted earlier as a part of this program provided excellent (and probably more easily used) data for fatigue analysis and design.

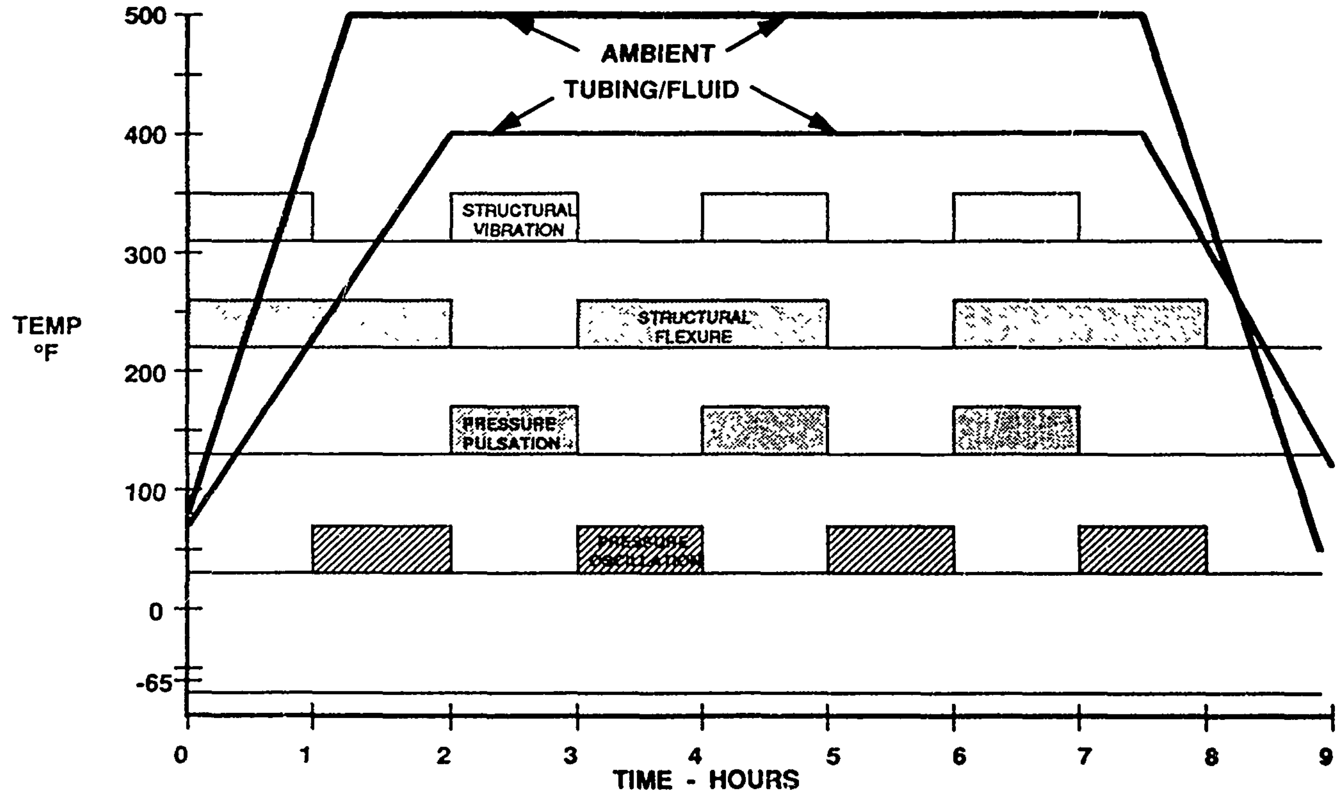


FIGURE 51: TYPICAL THERMAL CYCLES

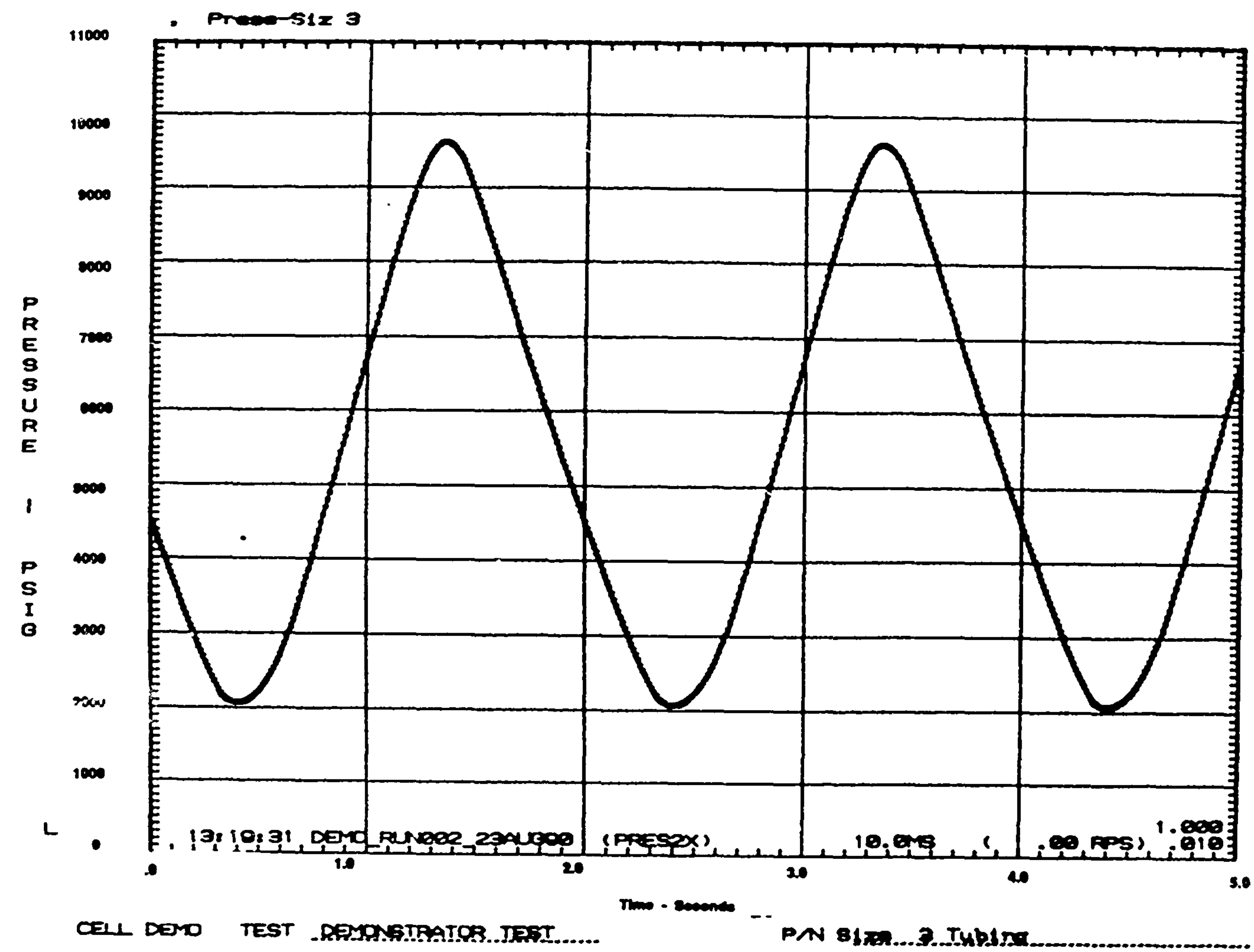


FIGURE 52: TYPICAL SINUSOIDAL PRESSURE OSCILLATION

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon component tests (Phase I, II, and III), the following listed conclusions were drawn. In most instances, these conclusions were verified and amplified by the demonstrator tests of Phase III.

1. A titanium plumbing system, using the components tested in this program, will reduce a plumbing system's weight and vulnerability as well as improve the system reliability and maintainability.

2. All components tested (tubing, fittings, hoses, swivels and quick disconnects) can be considered more than adequate for application to 8,000 psi, 400° F aircraft hydraulic systems in sizes up to and including 15/16 inch. However, based upon the 15/16-inch-diameter fitting tests, the dynamic beam fitting types appear to be marginal.

3. O-ring seal failure contributed to many of the component failures. These failures were due primarily to the fact that no hydraulic seals have been developed to operate at 8000 psi in a 400°F and above temperature environment. It is possible the number of failures that occurred at 400°F would have been greatly reduced had the operating temperature range been in the area of 275°F to 350°F.

4. S-N curve-type flexure and sine wave pressure impulse tests are much more satisfactory than the tests currently conducted under MIL-F-18280 (damped wave) for the following reasons:

   a. S-N curve-type testing provides a more accurate basis to compare different types of components .

   b. S-N curve-type testing provides the basic type of performance information needed by the designer to design and install an optimum hydraulic plumbing system.

   c. S-N curve-type testing shortens the test time required and reduces the test costs involved to obtain data on a given number of test specimens.

   d. S-N testing provides a basis for looking at different loading conditions and/or cycles using a Goodman Constant Life Diagram.

5. More work is needed in the area of 8000 psi fitting and other hardware design to develop their full capabilities.

   a. Institute a program to procure, test and evaluate 8000 psi hydraulic plumbing hardware,in significant production quantities, made by low-cost production processes.

   b. Associated with item 1, institute a program to evaluate titanium tubing, procured from at least three potential suppliers, in terms of cost, performance, quality, formability and fabricability.

   c. There is no program being considered to conduct qualification testing on 8000 psi tubing.

APPENDIX A

PRELIMINARY PROCUREMENT SPECIFICATION

PREPARED BY		NUMBER
D. E. Blanding	**Rockwell International Corporation** **North American Aircraft Operations**	L272C8000
APPROVALS		TYPE
J. D. [illegible] 2/24/87	**SPECIFICATION**	DATE 20 January 1987
		SUPERSEDES SPEC. DATED:
	FSCM NO. ________	REV. LTR. / PAGE 1 of 11

TITLE

TUBING, 3AL-2.5V TITANIUM, ALLOY, SEAMLESS, HYDRAULIC, 8000 PSI, AIRCRAFT

1. SCOPE

1.1 Scope. This specification covers cold worked and stress relieved, seamless, 3Al-2.5V titanium alloy tubing intended for high-pressure aircraft hydraulic systems and other structural components requiring high strength and oxidation resistance to 600°F.

2. APPLICABLE DOCUMENTS.

2.1 Applicability. The following documents, of the latest issue in effect, form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

2.1.1 Government Documents

SPECIFICATIONS

Military

MIL-I-6866	Inspection, Penetrant Method
MIL-I-25135	Inspection Material, Penetrant

STANDARDS

Federal

FED-STD-184	Identification Marking of Aluminum, Magnesium, and Titanium

2.1.2 Non-Government Documents

American National Standards Institute

ANSI B46.1	Surface Texture, Roughness, Waviness and Lay

Society of Automotive Engineers

AMS 2249	Chemical Check Analysis Limits - Titanium and Titanium Alloys
AMS 4944C	Titanium Alloy Tubing, Seamless, Hydraulic 3.0 AL-2.5V Cold Worked, Stress Relieved

American Society for Testing and Materials

ASTM E8	Methods of Tension Testing of Metallic Materials

3. REQUIREMENTS

3.1 General Material Requirements

3.1.1 Material used to manufacture 3Al-2.5V titanium alloy tubing shall be produced by multiple melting consumable electrode practice, in which all stages of melting shall be accomplished in a high vacuum atmosphere except that one stage may be accomplished in an inert atmosphere at a pressure slightly above the ambient.

3.1.2 All tubing shall be supplied in the cold worked and stress relieved condition, and shall have a cold worked alpha beta microstructure with no evidence of processing above the beta transus temperature.

3.2 Tubing Material Composition. The tubing material shall be Ti-3Al-2.5V alloy having the following chemical composition:

Element	Percent ***
Aluminum	2.5 to 3.5
Vanadium	2.0 to 3.0
Iron	0.30 maximum
Oxygen	0.12 maximum
Carbon	0.05 maximum
Nitrogen	0.02 maximum
Hydrogen*	0.0150 maximum
Yttrium	0.005 maximum
Other elements, each**	0.10 maximum
Other elements, total**	0.40 maximum
Titanium	Remainder

* A final analysis shall be made on a representative tubing sample from each lot after all processing is complete.

** Need not be reported.

*** Chemical check analysis limits shall be in accordance with AMS 2249.

3.3 Product Characteristics

3.3.1 Dimensional Limits. The tubing shall be at or within the dimensional limits of Table 1.

TABLE 1.

TUBING DIMENSIONAL* LIMITS 1/

NOM. OD	NOM. 2/ Wall-Thickness	OD MIN.	OD MAX.	Wall Thickness MIN.	Wall Thickness MAX.
3/16	.021	.188	.190	.020	.023
5/16	.035	.313	.316	.033	.039
7/16	.050	.438	.441	.048	.055
9/16	.064	.563	.567	.061	.070
11/16	.077	.688	.692	.073	.085
13/16	.092	.813	.817	.087	.101
15/16	.105	.938	.942	.100	.116

1/ These limits shall apply to variations due to any cause or combination of causes, including ovality and eccentricity.

* All dimensions are in inches.

2/ Tubing wall thickness shall not vary more than +10%, -5% (per AMS 4944C)

3.3.1.1 Minimum Wall Thickness - The minimum wall thickness for all tubing shall be 0.020 inch.

3.3.1.2 Straightness - The tubing shall not deviate from a straight tubing envelope by more than 0.025 inch in any 1 foot length and not more than 0.125 inch in any 5 foot length.

3.3.2 Surface Condition:

3.3.2.1 OD Surface - Shall show a uniform surface finish; material may be removed from the wall thickness as a finishing operation. Soft, belt polishing is permissible; traces of the polishing marks may remain after the operations.

3.3.2.2 ID Surface - Shall show a uniform finish.

3.3.2.3 Surface Texture - Shall be not greater than 63 RMS on the ID and be not greater than 32 RMS on the OD.

3.3.3 Tube Attachment - The method used to attach the tubing to permanent and detachable fittings shall be of a quality compatible with the design and performance requirements of the specification, and shall be optimized for minimum weight.

3.3.4 Operating Pressure - The tubing shall be designed for the following pressure conditions:

Normal Operating:	8000 Psig
Proof:	16000 Psig
Burst:	24000 Psig

3.3.5 Mechanical Properties

3.3.5.1 Tensile Properties - Tubing shall have the following tensile properties.

Ultimate tensile strength, psi	125,000
Tensile yield strength at 0.2 percent	105,000 offset, psi
Elongation percent in 2 inches	15%

3.3.5.2 Pressure Requirement. Tubing shall show no bulges, ruptures, or leaks when subjected to an internal hydrostatic pressure sufficient to cause a tensile stress of 105,000 psi in the tubing wall, except that a diametric permanent set of 0.002 inch per inch of diameter is acceptable. The hydrostatic test pressure shall be calculated according to the following equation.

$$p = 105{,}000 \times \frac{D^2 - d^2}{D^2 + d^2}$$

where:

p is test pressure in psi

D is the measured outside diameter, inches

d is the measured inside diameter, inches

3.3.6 Deformation Capabilities.

3.3.6.1 Flaring. A sample of tubing shall be flared to a diameter at least 1.2 times the original diameter without cracking or indications of defects when tested in accordance with 4.3.7. The flared zone as defined in Figure 3 shall be sound, uniform, smooth, and free from cracks on the inside or outside surfaces.

3.3.6.2 Bending. Tubing shall not develop cracks, tears, breaks, wrinkles or other flaws when bent, at room temperature, 180 degrees around a suitable mandrel of diameter equal to five times the outside diameter of the tubing. This is equivalent to a centerline bend radius of three times the tube outer diameter (3 D bend) when measured from the center of mandrel to the centerline of the tube bend. An internal mandrel or tube filler shall not be used to restrict flattening in the bend to a maximum of 3 percent of the nominal outside diameter of the tube.

3.3.6.3 Flattening. The tubing shall not exhibit cracks, seams, ruptures, opened die marks or polishing marks, or other defects on the inside or outside surfaces after flattening when tested in accordance with 4.3.4.

3.3.7 Identification and Marking. Tubing shall be marked throughout its entire length with two diametrically opposed continuously repeated sequences of symbols providing the following information:

(1) Supplier (name or trademark)

(2) Material Specification (L272C8000X, where X stands for the current revision designation).

(3) Nominal diameter.

(4) Nominal wall thickness.

(5) Lot number.

(6) Material designation (Ti-3Al-2.5V)

(7) Type of tubing (Seamless)

Blank spaces between or within marking sequences shall not exceed one inch in length.

The markings shall have no deleterious effect on the tubing and shall be in accordance with FED-STD-184.

3.3.8 Cleanliness. Both the inside and outside surfaces of all tubing shall be free from scale, oxygen-enriched surface metal, surface contamination, and surface residues which would cause embrittlement. Surfaces shall be free from grease and metallic particles.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. The supplier shall be responsible for the performance of all inspection requirements specified herein. Rockwell and its subcontractor reserve the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure that suppliers and services conform to prescribed requirements.

4.1.1 Supplier Approval. All facilities and procedures used by the supplier to fabricate, clean, test, and inspect tubing to be procured by Rockwell International requirements.

4.1.2 Procedure Documentation. Written procedure controlling fabrication, processing, inspection, and/or testing of material shall be maintained by suppliers. These procedures require Rockwell International concurrence.

4.2 Quality Conformance Inspection.

4.2.1 Quality inspection shall consist of all the tests of 4.3. (See Note 6.1.)

4.3 Tests.

4.3.1 Penetrant Inspection. All tubing shall be 100 percent fluorescent penetrant inspected externally to determine conformance to 3.3.4.1. Penetrant inspection shall be accomplished in accordance with MIL-I-6866, Type I, Method A or B, using a penetrant family that provides a sensitivity level equal to or better than Group VI of MIL-I-25135. Penetrant inspection shall be accomplished after all processing is complete.

4.3.2 Ultrasonic Inspection. Each length of tubing shall be ultrasonically inspected to detect any internal defects for verifying conformance to the requirements of paragraph 3.3.4.2. In compliance with 4.1.1 and 4.1.3, detailed ultrasonic inspection procedures shall be submitted to Rockwell International for approval prior to use.

4.3.3 Chemical Analysis.

4.3.3.1 A complete chemical analysis shall be made and the results reported for each heat of tubing material to verify conformance with 3.2.

4.3.3.2 A hydrogen analysis shall be made and the result reported on one representative sample of tubing from each lot of completely processed tubing to verify conformance with 3.2.

4.3.4 Flattening. Flattening test samples shall be of the full section of the tube and not less than 2 inches in length. A minimum of two samples from each lot (6.2) shall be tested. The samples shall be sectioned longitudinally in a diametral plane and flattened between parallel plates under a gradual load applied perpendicularly to the longitudinal axis. After flattening, the inner and outer surfaces shall be examined at 50X magnification for conformance to 3.3.6.3.

4.3.5 Tensile Properties. One sample of tubing shall be selected from each lot and tested in accordance with ASTM E8. The rate of strain shall be 0.003 to 0.007 inch per inch per minute through the yield strength and shall then be increased so as to produce failure within one additional minute. Tensile properties shall be in accordance with 3.3.5.1.

4.3.6 Pressure Test. One 8-inch length of tubing from each lot shall be subjected to an internal hydrostatic pressure calculated in accordance with 3.3.5.2. This pressure shall be applied and maintained for a minimum of two minutes. After testing, the sample shall be penetrant inspected for defects. Evidence of such defects shall cause the lot of tubing to be subject to rejection.

4.3.7 Bending Test. Two specimens of suitable size shall be selected from each lot. The specimens, when subjected to the bending requirements of 3.3.6.2, shall withstand the test with no evidence of cracking or metal separation when examined at 10X magnification.

4.3.8 Wall Thickness. Measurements of wall thickness shall be made at 90-degree intervals around each end, a minimum of 1/4 inch from the end, of each length of tubing. Tubing failing to meet the wall thickness limits specified in 3.3.1 shall be rejected.

4.3.9 Diameter. Measurements of outside diameter shall be made at 90-degree intervals around each end, a minimum of 1/2 inch from the end of each length of tubing. Measurements of outside diameter shall also be made at every 2-foot interval of length for each tube. Tubing failing to meet the diameter limits specified in 3.3.1 shall be subject to rejection.

4.3.10 Straightness. Measurements for straightness shall be made on each length of tubing at 90-degree intervals around the periphery of the tube and at 3-foot intervals of length. Tubing deviating from the straightness tolerances specified in 3.3.2 shall be subject to rejection.

4.3.11 Cleanliness. Each tube length shall have a clean, lint-free, white cloth drawn through the tubing. Any evidence of metallic particles, grease or other residue on the cloth shall result in rejection of the tubing.

4.3.12 ID Surface Inspection. One length of tubing shall be selected from each lot. A 6-inch section shall be removed from each end of the tube. These sections shall be split longitudinally and the ID surface visually examined to determine conformance to 3.3.3.1.

4.3.13 OD Surface Inspection. To determine conformance to 3.3.3.2 surface roughness measurements shall be obtained in the longitudinal direction by the method of ANSI B46.1.

4.3.14 Metallographic Analysis. A metallographic examination at 100X magnification shall be performed to determine conformance to 3.1.2, 3.3.3.3 and 3.3.3.4 on each lot of material using the same section of tubing analyzed for hydrogen content in 4.3.3.2.

4.3.15 Resampling and Retest. If any specimen used in the above tests fails to meet the specified requirements, acceptance of the product may be based on the results of testing five additional specimens for each original nonconforming specimen, all such additional specimens shall conform to specified requirements. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the material represented. Further testing shall not be permitted. Results of all tests shall be reported.

4.3.16 Processing Changes. No deviations from the manufacturing procedures are permitted after approval of the supplier's qualification testing without written concurrence from Rockwell International.

4.4 Reports. The supplier shall furnish, with each shipment of tubing, three copies of a report giving all results of testing for conformance to the requirements of this specification. Separate reports shall be submitted for each lot of tubing. The reports shall include the following information:

a. Rockwell International purchase order number

b. Heat number and lot identification

c. Material specification number: L272C8000X (where X = current revision letter)

d. Size

e. Quantity of each lot

f. Heat treatment of material and test specimens

g. Results of tests conducted in accordance with 4.3

5. PREPARATION FOR DELIVERY

5.1 Packaging. Each length of tubing shall be encased in a separate sleeve to ensure maximum protection during shipment, handling, and storage. All tubes shall be packed or crated consistent with the best commercial practices to prevent damage during shipment.

5.1.1 Marking of Containers. Shipping containers, crates, boxes, or bundles shall be marked to give the following information.

a. Material - Titanium 3Al-2.5V

b. Purchase order number

c. Purchaser's material specification: L272C8000 (where X = current revision letter)

d. Size and quantity

e. Manufacturer's name or trademark

f. Lot number

NOTES

6.1 Reduction of Test Requirements. If the supplier can furnish statistical evidence verifying that his processes are controlled and fabricated tubing is of consistent quality, the supplier may, with written concurrence from Quality Control of Rockwell International, reduce the test requirements of 4.2 to a commensurate level.

6.2 Lot Definition. A lot shall consist of a continuous production run of tubing, of one diameter and wall thickness from a single heat of material, manufactured and processed in the same manner, including heat treatment and cold working and submitted to inspection at one time.

PREPARED BY	Rockwell International Corporation North American Aircraft Operations **SPECIFICATION** FSCM NO. ________	NUMBER L271C8000	
D. E. Blanding		TYPE	
APPROVALS [signature] 1/29/87		DATE 20 January 1987	
		SUPERSEDES SPEC. DATED:	
		REV. LTR.	PAGE 1 of 18

TITLE

HOSE ASSEMBLIES, HYDRAULIC, 8000 PSI, AIRCRAFT

1. SCOPE

1.1 Scope. This specification covers hose assemblies for use in 8000 psi aircraft lightweight hydraulic systems.

1.2 Classification. Hose assemblies covered by this specification shall be of the following types:

Type I - Hose assemblies with fire sleeves.
Type II - Hose assemblies without fire sleeves.

2. APPLICABLE DOCUMENTS

2.1 Issues of Documents. The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1.1 Government Document

SPECIFICATION

Federal

P-D-680 - Dry Cleaning Solvent
TT-I-735 - Isopropyl Alcohol

Military

MIL-C-5501 - Caps and Plugs, Protective, Dust and Moisture Seal

MIL-H-6083 - Hydraulic Fluid, Petroleum Base, for Preservation and Testing

MIL-H-83282 - Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft

MIL-P-116 - Preservation-Packaging, methods of

STANDARDS

Military

MIL-STD-100 - Engineering Drawing Practices

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-129 - Marking for Shipment and Storage

MIL-STD-130 - Identification Marking of US Military Property

MIL-STD-831 - Test Reports, Preparation of

2.1.2 Rockwell Documents

L273C8003 - Fittings, Fluid Connection, Aircraft, 8000 PSI

2.2 Other Publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or requests for proposal shall apply.

American Society for Testing and Materials

ASTM D412 - Tension Testing of Vulcanized Rubber
ASTM D571 - Testing Automotive Hydraulic Brake Hose

Society of Automotive Engineers

AMS 3380 - Hose, Polytetrafluoroethylene, TFD Fluorocarbon Resin, Wire Brade Reinforced

ARP 611 - Tetrafluoroethylene Hose Assembly Cleaning Methods

ARP 1055 - Fire Resistant and Fire Test Requirements

3. REQUIREMENTS

3.1 Metals. Metals used in the hose and fittings shall be corrosion resistant.

3.2 Design and Construction. The hose assembly shall consist of a seamless inner tube, reinforcement, and end fittings.

3.2.1 Inner Tube. Inner tube shall be of seamless construction of uniform gage. It shall have a smooth bore and shall be free from pitting or projections on the inner surface. Additives may be included in the compound from which the tube is extruded.

3.2.2 Reinforcement. The reinforcement shall conform to the applicable specification listed in 3.3. The reinforcement shall be so arranged over the inner tube as to provide sufficient strength and flexibility to insure conformance with the requirements specified herein.

3.2.3 Fluid Media. The hose assemblies shall be compatible both internally and externally with MIL-H-83282 and MIL-H-6083.

3.2.4 Fittings. End fittings for the hose assembly shall be the field-detachable type conforming to L273C8003 Type III. The outlet design shall be lip seal type or equivalent. Special ends, such as elbows and swivels, may be incorporated in the hose assembly.

3.3 Performance Characteristics.

3.3.1 Tube.

3.3.1.1 Tube Roll. The tube, without reinforcement, shall not leak, split, burst, nor show any other evidence of malfunction, when rolled and compressed.

3.3.1.2 Tube Proof Pressure. The tube, without reinforcement, shall not leak, burst, nor show any evidence of malfunction when held at the proof pressure specified in Table I.

TABLE I. Proof Pressure and Gap Tolerance.

Size	Flattening Gap Max. (Inches)	Rounding Gap Min. (Inches)	Proof Pressure (psi)
-3 -5 -7 -9 -11 -13 -15	TBD	TBD	TBD

3.3.1.3 Tensile Strength. The longitudinal tensile strength for all sizes of tubes shall be 2,200 psi minimum at $77^{\circ} \pm 2^{\circ}F$.

3.3.2 Hose Assembly. The hose assembly (complete with reinforcing wires and assembled with fittings) shall meet the following performance requirements.

3.3.2.1 Proof and Burst Pressures. The hose assembly shall withstand the proof pressure listed in Table II without malfunction or leakage. The hose assembly shall withstand burst pressure listed in Table II without rupture.

3.3.2.2 Elongation and Contraction. The hose assembly shall not change in length by more than $\pm$ 0.20 inch in 10 inches of length, when subjected to the operating pressure shown in Table II for a minimum of five minutes.

3.3.2.3 Volumetric Pressure. The volumetric expansion of the hose assemblies shall not exceed the limits specified in Table II.

3.3.2.4 Leakage. The hose assembly shall not leak when subjected to two pressure cycles of 70 percent of minimum burst pressure of Table II.

3.3.2.5 Room Temperature Burst Pressure. The hose assembly shall not leak nor burst at any pressure specified in Table II.

3.3.2.6 Thermal Shock. The hose assemblies shall not leak nor show any evidence of malfunction when exposed to thermal shock of -65° to $400^{\circ}F$.

TABLE II. Physical Requirements of High Pressure Hose Assemblies.

Size Dash No.	Operating Pressure (Max. psi)	Proof Pressure (Min. psi)	Burst Pressure Room Temp. (Min. psi)	Burst Pressure Hi Temp. (Min. psi)	Min. Bend Radius (inside of Bend) (Inches)	Elongation Contraction For a 10-In Sample(Inch)	Cubical Expansion (cc/in.)
-3	8000	16,000	24,000	24,000			
-5	8000	16,000	24,000	24,000			
-7	8000	16,000	24,000	24,000			
-9	8000	16,000	24,000	24,000	TBD	TBD	TBD
-11	8000	16,000	24,000	24,000			
-13	8000	16,000	24,000	24,000		TBD	TBD
-15	8000	16,000	24,000	24,000			

3.3.2.7 Impulse. The hose assemblies shall be capable of withstanding 10,000,000 impulse cycles at 400°F.

3.3.2.8 Assembly Flexibility. The hose assembly shall not leak nor show any evidence of malfunction, when flex-cycled from -65° to 400°F.

3.3.2.9 Over-tightening Torque. The fitting shall withstand the overtightening torque values specified in Table III.

TABLE III. Overtightening Torque Values

Fitting Size	Pound Inches
-3	
-5	
-7	
-9	TBD
-11	
-13	
-15	

3.3.2.10 Conductivity. Hose assemblies of size -3 through -8 shall be capable of conducting a direct current equal to or greater than 6 microamperes when a potential of 1,000 volts dc is applied.

3.4 Fire Resistance. Type I hose assemblies shall have fire sleeves which meet the requirements of ARP 1055, Type II, Class B. The fire sleeve shall cover the end fitting socket, shall be permanently retained, and shall be compatible with MIL-H-83282 fluid.

3.5 Length. Hose assembly lengths and tolerances shall be as specified in the contract.

3.6 Weight. The hose assembly shall be the lightest weight practical consistent with good design practice that is capable of meeting the requirements of this specification.

3.7 Item Marking.

3.7.1 Part Numbering of Interchangeable Parts. All parts having the same manufacturer's part number shall be functionally and dimensionally interchangeable. The item identification and part number requirements of MIL-STD-100 shall govern the manufacturer's part numbers and changes thereto.

3.7.2 Identification of Product. Hose assemblies shall be marked for identification in accordance with MIL-STD-130. The following special marking shall be added:

a. Fittings: The manufacturer's name or trade mark shall be permanently marked on all end fittings.

b. Assembly: A permanent marking on the fitting or a permanent band on the hose shall be used. The band shall be no wider than 3/4 inch and shall not impair the flexibility or the performance of the hose. The marking on the fitting or band shall include the following information:

Assembly manufacturer's name or trade mark.
Hose manufacturer's Federal Code number.
Operating pressure "8000 psi".
Pressure test symbol "PT".
Date of hose assembly manufacture expressed in terms of month and year.

3.8 Workmanship. The hose assembly, including all parts, shall be constructed in a thoroughly workmanlike manner. All surfaces shall be free from burrs. All sealing surfaces shall be smooth.

3.8.1 Cleaning. All hose assemblies shall be free from oil, grease, dirt, or any other foreign materials both internally and externally. Unless otherwise specified, hose assemblies shall be cleaned to Class II of ARP 611, except that no chlorinated cleaning solutions may be used in the cleaning process.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the contractor may use his own or any other facilities suitable for identification and part number requirements specified herein unless disapproved by the procuring activity. The procuring activity reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of Inspections. The inspection requirements specified herein are:

a. Performance tests (see 4.4)
b. Quality conformance inspections (see 4.5)
c. Packaging instructions (see 5.0)

4.3 Inspection Conditions.

4.3.1 Fitting Ends. Quality conformance inspection shall be conducted on assemblies using straight type swivel ends.

4.3.2 Preparation of Specimen.

4.3.2.1 Sample Lengths. Unless otherwise specified, assemblies shall be 12 inches minimum hose length.

4.3.2.2 Oil Aging. Oil-aged samples shall be filled with MIL-H-83282 fluid and soaked in an air oven at a temperature of 400°F for 7 days. All air shall be excluded from the bore of the assembly during the test period. No pressure shall be applied to the assembly during the aging period..

4.3.2.3 Air Aging. Air-aged samples shall be kept in air at a temperature of 400°F for 7 days.

4.3.2.4 Unaged Assemblies. Unaged assemblies shall be as shipped from the hose assembly manufacturer.

4.3.3 Test Fluids. Unless otherwise specified, the pressure test fluid shall be hydraulic oil conforming to MIL-H-83282 or water. Unless otherwise specified, all pressures shall have a tolerance of ±100 psi.

4.3.4 Temperature Measurements. Unless otherwise specified, temperature measurements shall be taken within six inches of the hose assemblies under test. Unless otherwise specified, all temperature shall have a tolerance of ±5°F.

4.4 Performance Tests. Test Sample shall be tested in accordance with Table IV.

TABLE IV. Performance Tests

Tests	Requirement Paragraph	Test Method Paragraph
Examination of product	3.3, 3.6 thru 3.8	4.6.1
Tube roll and proof test	3.3.1.1, 3.3.1.2	4.6.2
Tube tensile strength	3.3.1.3	4.6.3
Proof pressure test	3.3.2.1	4.6.4
Elongation and contraction test	3.3.2.2	4.6.5
Volume expansion test	3.3.2.3	4.6.6
Leakage test	3.3.2.4	4.6.7
Room temperature burst pressure test	3.3.2.5	4.6.8
Thermal shock test	3.3.2.6	4.6.9
Impulse test	3.3.2.7	4.6.10
Assembly flex test	3.3.2.8	4.6.11
Overtightening torque test	3.3.2.9	4.6.12
Conductivity test	3.3.2.10	4.6.13
Fire Resistance	3.4	4.6.14

4.4.1 Test Report, Test Samples, and Data for the Procuring Activity. When the tests are conducted at a location other than the laboratory of the procuring activity, the following shall be available for furnishing to that activity:

a. Test report in accordance with MIL-STD-831, and shall include a report of all tests and outline description of test conditions.

b. Test samples that were tested and three untested samples of each size if requested by the qualifying activity within one year subsequent to submittal of Qualified Products List request.

c. Engineering data in the form of detail and assembly drawings. The assembly drawings shall have a cut away section showing all details in their normal assembly position and shall carry part numbers of all details and subassemblies.

d. List of sources of hose or hose components including source's name and product identification for inner tube, hose and assembly.

4.5 Quality Conformance Inspections. Quality conformance inspections shall be accomplished on hose assemblies for delivery in accordance with the following and the procedures in MIL-STD-105.

a. Individual tests (see 4.5.1) (100 percent inspection).

b. Sampling tests (see 4.5.2).

c. Periodic control tests (see 4.5.3).

4.5.1 Individual Tests. Each hose assembly shall be subjected to the following tests:

a. Examination of product of 4.7.1.

b. Proof pressure tests of 4.7.4.

NOTE: Production samples that are proof pressure tested with water should be air dried prior to capping.

4.5.2 Sampling Tests. The following tests shall be performed on hose assemblies individually selected at random from each lot in order listed. A sampling test lot shall consist of not more than 6,600 feet of hose all of one dash size.

a. Elongation and contraction test of 4.7.5.

b. Leakage test of 4.7.7.

c. Room temperature burst pressure test of 4.7.8.

4.5.3 Periodic Control Tests. The following tests shall be performed on eight hose assemblies (for each test) individually selected at random from each complete lot. A periodic control test lot shall consist of no more than 20,000 feet of hose, all of one dash size, manufactured under essentially the same conditions.

a. Impulse test of 4.7.10 (unaged samples only).

b. Conductivity test of 4.7.13.

4.5.4 Rejection and Retest. Where one or more items selected from a lot fails to meet the specification, all items in the lot shall be rejected.

4.5.4.1 Resubmitted Lots. Once a lot (or part of a lot) has been rejected by a procuring activity, before it can be resubmitted for tests, full particulars concerning the cause of previous rejection and the actions taken to correct the defects in the lot shall be furnished, in writing, by the supplier.

4.5.5 Switching Procedures. Switching inspection severity levels, for example, from normal to tightened inspection, shall be in accordance with MIL-STD-105. All inspection plans shall be single sample plans with an AQL of 1.0 percent at special inspection level S-2.

4.5.6 Destructive Test Sample. Prior to testing, a letter (D) shall be impression stamped on each end fitting of those assemblies used for destructive tests of 4.5.2 and 4.5.3.

4.6 Methods of Examination and Test.

4.6.1 Examination of Products. Each length of tubing shall be examined to determine compliance with this specification with respect to material, size, workmanship, and dimensions.

All hose assemblies shall be visually inspected to determine conformance to this specification and inspected for broken or missing reinforcing wires or any other evidence of malfunction which shall be cause for rejection. Crossed over reinforcing wires shall not be cause for rejection.

4.6.2 Tube Roll and Proof Test. Each length of tubing shall be subjected to a tube roll and proof test in accordance with AMS 3380, except that the flattening gap, rounding gap, and proof pressure shall be as specified in Table I. The test fluid shall be either air or water.

4.6.3 Tube Tensile Strength. Size -8 tubes and under shall be subjected to tensile strength tests in accordance with ASTM 0412, except that the separation shall be as specified in 3.5.1.3. The transverse tensile strength need not be tested.

4.6.4 Proof Pressure Test. All hose assemblies shall be pressure tested to the values specified in Table II for not less than 30 seconds and not more than five minutes. The test fluid may be either water or hydraulic oil conforming to MIL-H-83282. Hose assemblies having fire sleeves shall be tested using water as the medium. Proof pressure shall be held a minimum of two minutes during which time the fire sleeves shall be pulled back from the end fittings. Any evidence of leakage from hose or fittings or any other evidence of malfunction shall constitute failure.

4.6.5 Elongation and Contraction Test. Two hose assemblies of each size shall be subjected to the elongation and contraction test. With the hose held in a straight, unpressurized condition, a 10-inch gage length shall be marked off on the hose and the hose then pressurized. After 5 minutes, while still pressurized, the gage length shall be re-measured and the change in length calculated. Hose elongation shall conform to the requirements specified in Table II.

4.6.6 Volumetric Expansion Test. Two hose assemblies of each size shall be tested in accordance with ASTM 0571 using an operating pressure of 8000 psi. The volumetric expansion of the test assemblies shall be in accordance with values shown in Table II.

4.6.7 Leakage Test. Two hose assemblies of each size shall be pressurized to 70 percent of the minimum room temperature burst pressure shown in Table II, and held for five minutes minimum. The pressure shall then be reduced to zero psi, after which it shall be raised to 70 percent of the minimum burst pressure for a final 5-minute check. Any evidence of leakage from hose or fittings, hose burst, fitting blow off or any other evidence of malfunction shall constitute failure.

4.6.8 Room Temperature Burst Pressure Test. Two hose assemblies of each size shall be subjected to a pressure sufficient to burst the assemblies using a rate of pressure rise equal to 20,000 $\pm$ 5,000 psi per minute. The assemblies shall be observed throughout the test and the type of failure and the pressure at which failure occurred shall be recorded. The assemblies shall not leak nor show any evidence of malfunction at any pressure below the specified pressure listed in Table II.

4.6.9 Thermal Shock Test. The thermal shock test shall be as follows:

a. Two hose assemblies of each size shall be subjected to this test. One assembly shall be air-aged and one assembly shall be unaged. The assemblies shall be subjected to the proof pressure specified in Table II for a minimum of five minutes.

b. The test assemblies shall then be mounted, empty, in a high temperature test setup (typical setup shown on Figure 1) and the ambient temperature reduced to -50 ± 20°F for a minimum of two hours. At the end of this period, while still at this temperature, high temperature test fluid at a temperature of 400° shall be suddenly introduced at a minimum pressure of 50 psi. Immediately after the hot oil has filled the assembly, the pressure shall be raised to the proof pressure specified in Table II for a minimum of five minutes. Not more than 15 seconds shall elapse between the introduction of the high temperature oil at 50 psi and the raising of the pressure to proof pressure.

c. The test assemblies shall then be filled with MIL-H-83282 fluid at a pressure of 75 psi ± 25 psi and soaked with fluid and ambient temperature maintained at 400°F for one hour. At the end of this period the assembly shall be pressurized to the proof pressure specified in Table II for a minimum of five minutes. The pressure shall be released and while still maintaining 400°F, the pressure shall be increased at the same rate of rise as specified in 4.7.8 until failure is obtained. The hose assembly shall be under continuous observation during the preceding test and the pressure at which failure occurred and the type of failure shall be recorded.

d. During part (b), and the proof portion of part (c) of the test, any evidence of leakage from the hose or fittings, hose burst, fitting blow off or any other evidence of malfunction shall constitute failure. During the burst portion of (c), any of the above occurring below the high temperature burst pressure shown in Table II shall constitute failure.

4.6.10 Impulse Test. The impulse test shall be as follows:

a. Two test assemblies shall be oil aged, two shall be air aged, and two shall be unaged. The assemblies shall then be subjected at room temperature to the proof pressure specified in Table II for a minimum of five minutes.

b. The test assemblies shall be connected to rigid supports and bent in a U-shape with a bend radius as specified in Table II at the apex of the bend.

c. Impulse pressure conforming to the curve shown in Figure 2(a) or (b) shall be applied to the inlet manifold at a rate not below the minimum specified. Electronic measuring equipment shall be used to monitor the wave form. The test fluid shall be MIL-H-83282.

A minimum of 10,000,000 impulses shall be conducted at 400°F. Any evidence of leakage from the hose or fittings prior to the completion of 10,000,000 cycles for all sizes shall constitute failure.

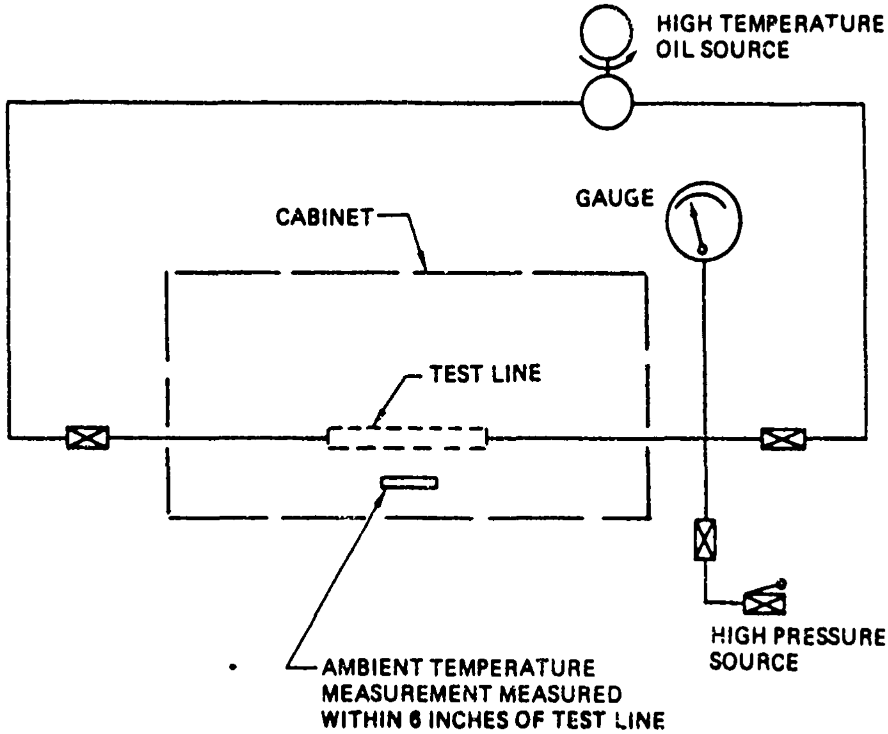


FIGURE 1. Typical Setup for High Temperature Pressure Testing.

4.6.11 Assembly Flex Test. Two hose assemblies of each size shall be mounted in the assembly flex test setup as illustrated on Figure 3 and subjected to the following test sequence. The assemblies shall be filled with oil as specified in 4.5.3. Temperatures stated are both fluid and ambient. Flexing shall occur at a rate of 70 ± 10 cpm during portions (c), and (d), and (e).

a. The test assemblies shall be soaked with no pressure or flexing at a temperature of -65°F ± 5°F for a minimum of one hour.

b. With the temperature still at -65°F and no flexing, the test assemblies shall be pressurized for a minimum of 5 minutes (first cycle only) to the proof pressure specified in Table II.

c. Flexing shall begin with the test assemblies pressurized to the operating pressure specified in Table II and with the temperature still at -65°F. A total of 4,000 cycles shall be completed.

d. With the pressure reduced to zero psi, flexing shall continue for 1000 cycles at -65°F.

e. Increase the temperature to 400°F. Conduct 1,000 flex cycles with the pressure at zero psi. The pressure shall then be increased to the operating pressure specified in Table II with the temperature held at 400°F. Flexing shall continue until an accumulated total of 80,000 cycles is reached.

f. Steps (a), (c), (d), and (e) shall be repeated for a total of five test sequences, i.e., 400,000 flexing cycles.

g. After completion of step (f) and with the temperature still at 400°F and no flexing, the test assemblies shall be pressurized to the proof pressure specified in Table II for a minimum of five minutes (last cycle only).

Any leakage from the hose or fittings, hose burst, fitting blow off, or any other evidence of malfunction during test shall constitute failure.

4.6.12 Overtightening Torque Test. Prior to this test the end fittings shall be lubricated with oil conforming to MIL-H-83282. The fittings shall be tightened to the applicable torque specified in Table III and then loosened. This sequence shall be repeated 15 times. After this sequence, there shall be no evidence of failure or deformation of the fitting assemblies, and the swivel nuts shall be free enough to permit turning on the nipple by hand. After the above tightening torque test sequence the tested end fittings shall be coupled to a length of hose and subjected to the proof pressure specified in Table II for five minutes. Any leakage shall be cause for rejection.

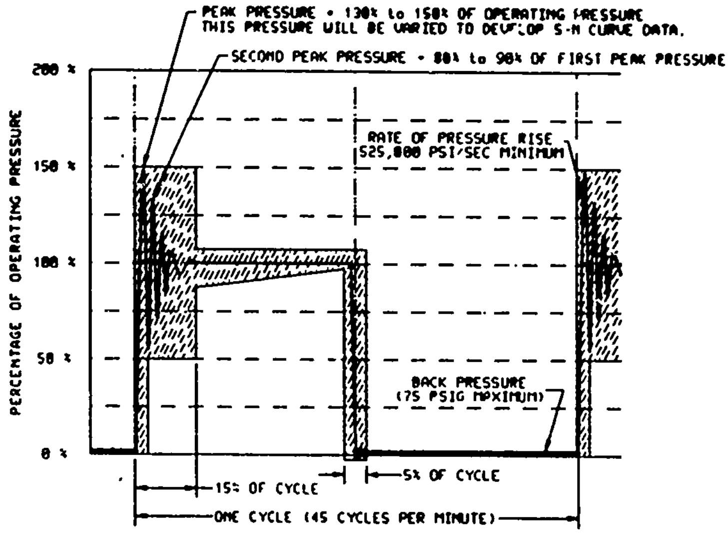


Figure 2(a) Damped Wave

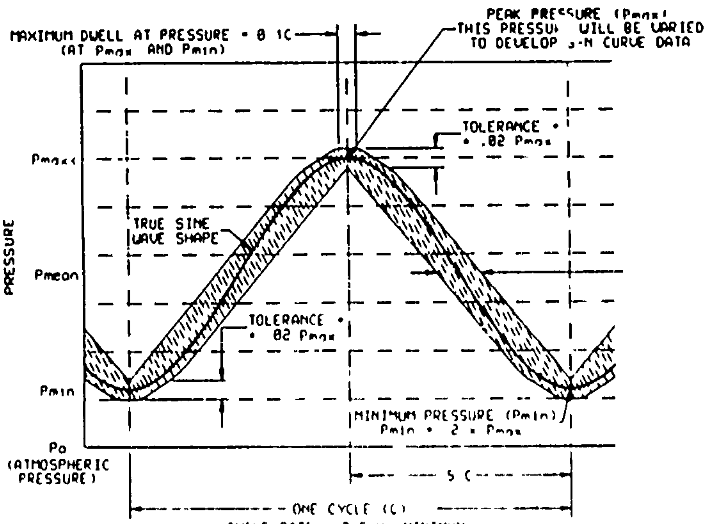
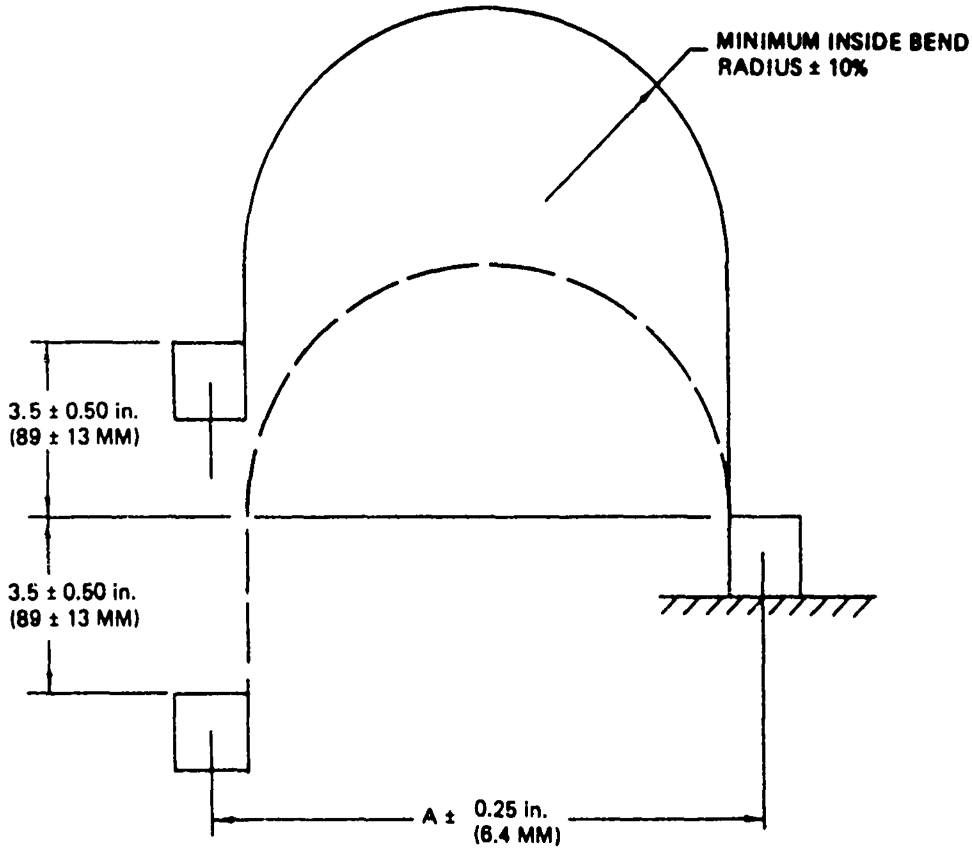


Figure 2(b) Sine Wave

FIGURE 2. Dynamic Pressure Impulses.



Hose Size	A Inches
-3	6-1/2
-5	10-5/8
-7	12-1/4
-9	14
-11	16-5/8
-13	18
-15	20-3/4

FIGURE 3. Assembly Flex Setup

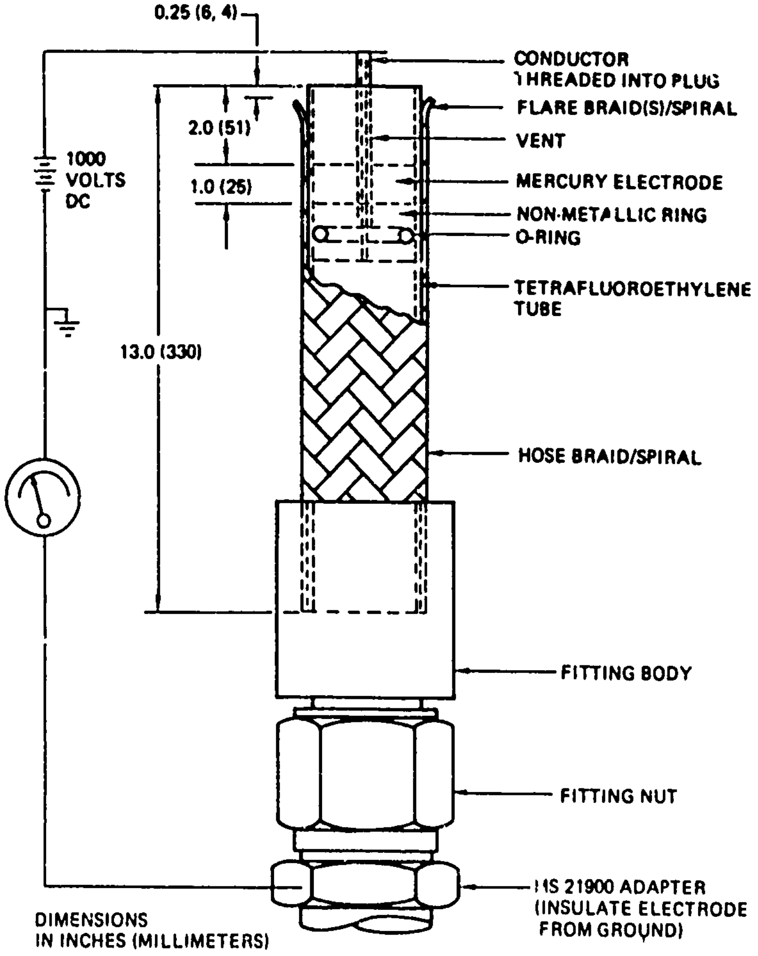


FIGURE 4. Conductivity Test Diagram.

4.6.13 <u>Conductivity Test</u>. The conductivity test shall be conducted as follows:

a. The test specimen shall be a length of hose (with braid and one end fitting) as shown on Figure 4. The inner surface of the tube shall be washed first with solvent conforming to P-D-680 and second with isopropyl alcohol conforming to II-I-735 to remove surface contamination, and then thoroughly dried at room temperature. The wire shall flare out as shown on Figure 2, to prevent contact with the end of the tetrafluoroethylene tube.

b. The test specimen shall then be arranged vertically as shown on Figure 4. The relative humidity shall be kept below 70 percent and room temperature between 60° and $90^{\circ}F$. One thousand volts maximum, d.c., shall be applied between the upper mercury electrode and the lower electrode.

c. The current shall be measured with an instrument with a sensitivity of at least one microampere (1×10^{-6} ampere).

4.6.14 <u>Fire Resistance</u>. Where fire resistance or fire proofing is specified as a requirement, qualification tests shall be conducted in accordance with the procedures and requirements specified in ARP 1055.

5. PACKAGING

The preservation-packaging and interior package marking shall be in accordance with the applicable group quality conformance inspection requirements of MIL-P-116. The inspection of the packing and marking for shipment and storage shall be in accordance with the quality assurance provisions of the applicable packing specification for the proper level and the marking requirements of MIL-STD-129. All openings shall be sealed with metal caps or plugs conforming to MIL-C-5501.

6.0 NOTES AND CONCLUDING MATERIAL

6.1 <u>Intended Use</u>. The hose assemblies covered by this specification are intended for use in aircraft 8000 psi hydraulic systems.

6.2 <u>Ordering Data</u>. The contract should specify the following:

a. Title, number, and date of this specification.
b. Type required (see 1.2).
c. Level of preservation and packaging and packing (see 5.0).
d. Samples subjected to destructive testing are not to be considered or shipped as part of the contract.
e. When fire resistance or fire proofing is required see 4.6.14.

PREPARED BY		NUMBER
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APPROVALS		TYPE
1/29/87	# SPECIFICATION	DATE 20 January 1987
		SUPERSEDES SPEC. DATED:
	FSCM NO. ________	REV. LTR. / PAGE 1 of 18

TITLE

FITTINGS, FLUID CONNECTION, AIRCRAFT, 8000 PSI

FORM NAO 131-H-1 REV 10-81 (▮ - INDICATES CHANGE)

1.0 SCOPE

1.1 Scope - This specification covers the basic design and test requirements for separable, permanent and boss fittings used in 8000 psi aerospace fluid systems.

1.2 Classification - Fittings covered by this specification shall be of the following classes:

Class I — Fittings which produce a permanent joint at fluid connections.

Class II — Fittings which produce a separable joint at fluid connections.

Class III — Fittings which are installed as ports in a component.

1.3 Fitting Definition - Fittings covered in this specification shall be capable of joining lines or components and sealing the joint thus made. Reliability and producibility are most important.

1.3.1 Class I fittings shall employ welded, brazed, shrink fit, internally swaged, externally swaged or other tube-to-fitting/tube-to-tube connection methods.

1.3.2 Class II fittings shall provide a reliable leakproof connection method for joining fitting mating halves or components. The design shall allow minor misalignment and provide line removal or installation at a separable joint.

1.3.3 Class III fittings shall employ a threaded male connection capable of providing a reliable, removable sealing element between detachable fittings and hydraulic components. The seal between the component and threaded male end of the fitting will be the supplier's recommended design and furnished by the supplier.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

2.1.1 Government Documents.

SPECIFICATIONS

Military

MIL-H-46170	Hydraulic Fluid, Rust-Inhibited, Fire Resistant,Synthetic Hydrocarbon Base
MIL-H-83282	Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft

SPECIFICATIONS (Continued)

MIL-S-5002	Surface Treatments and Metallic Coatings for Metal Surfaces of Weapons Systems
MIL-S-8879	Screw Threads, Controlled Radius Root with Increased Minor Diameter, General Specification for

STANDARDS

Military

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-831	Test Reports, Preparation of

2.1.2 Rockwell Documents

L272C8000	Tubing, 3AL-2.5V Titanium, Alloy, Seamless, Hydraulic, 8000 PSI, Aircraft

2.2 Other Publications - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

United States of America Standards Institute

B46.1 - 1962	Surface Texture (Surface Roughness, Waviness and Lay)

3.0 REQUIREMENTS

3.1 Materials - Detachable fittings and nuts shall be supplied from materials listed in Table I, and compatible with titanium 3AL-2.5V tubing per L272C8000.

Table I Materials

Type of Part	Material	Form	Specification
Nuts and straight or forged fittings	TBD	Bars, rods, plates, and forgings	TBD

3.2 Design and Dimensions - The design and dimensions of fittings and nuts shall be in accordance with the applicable NR approved supplier's drawing.

3.2.1 Passages

3.2.1.1 Drill Offset - On straight fittings where the fluid passage is drilled from each end, the offset between the drilled holes at the meeting point of the drills shall not exceed 0.015 inch. It shall be possible to pass through the fluid passage a ball whose diameter is 0.020 less than minimum diameter specified or the passage. This does not mean that the drilled passage may be smaller than that required by the applicable drawing.

3.2.1.2 Fluid Passages - On angle fittings, the cross-sectional area at the junction of the fluid passages shall be not smaller than the cross-sectional area of the smaller passage.

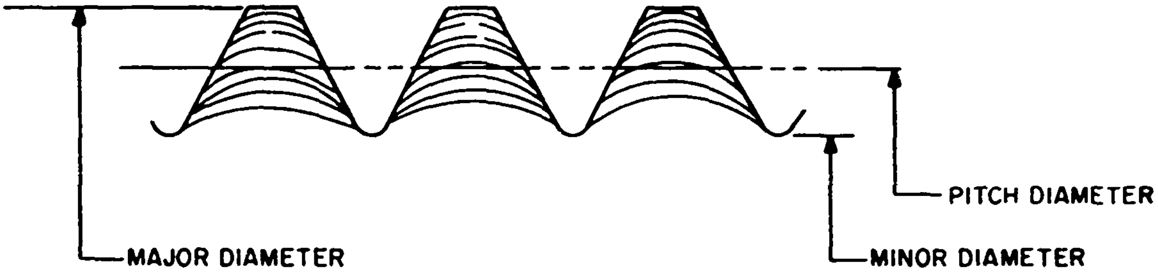
3.2.2 Threads - Threads shall conform to MIL-S-8879. Threads may be cut, ground, or rolled.

3.2.2.1 External Threads - The grain flows in rolled threads shall be continuous and shall follow the general thread contour, with the maximum density at the thread root as shown on Figure 1. Laps and seams, whose depths are within the limits of Table II, are acceptable on the crest, and the non-pressure thread flank above the pitch diameter. Laps and seams are not acceptable on any part of the pressure thread flank, in the thread root, or on the non-pressure thread flank extending from above to below the pitch diameter. Stress cracks are unacceptable.

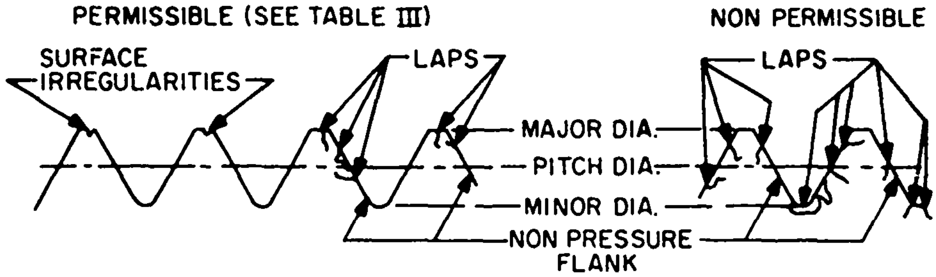
TABLE II.
Depth of Laps, Seams, Surface Irregularities, and Discontinuities in Rolled Threads

Fitting Size	Depth (Inch) (Max.)	Thread Size	
		II	III
-3 -5 -7 -9 -11 -13 -15	TBD		

3.2.3 Fitting-Nut Connection - The fittings and tube-fitting nuts shall mate in a lip seal or flareless arrangement and when assembled shall have positive sealing with zero leakage.



Grain flow in rolled threads



LAPS NOT EXCEEDING .0008 IN DEPTH ARE PERMISSIBLE IN THREAD RUNOUT AREA.

Laps & surface irregularities in threads

FIGURE 1. LAPS AND SURFACE IRREGULARITIES IN THREADS

TABLE III Fittings, Tube Material, Pressure and Stresses

				3Al-2.5V TITANIUM TUBING PER L272C8000	
TUBE O.D. (IN)	NOM. TUBE O.D. 1/	DASH SIZE	WORKING PRESSURE	NOM. TUBE WALL THICKNESS 2/ (IN)	*TOTAL MINIMUM STRESS LEVEL IN TUBE FOR FLEXURE
3/16	.1875	-3	8000 PSI	.021	36,000 PSI
5/16	.3125	-5	8000 PSI	.035	36,000 PSI
7/16	.4375	-7	8000 PSI	.050	36,000 PSI
9/16	.5625	-9	8000 PSI	.064	36,000 PSI
11/16	.6875	-11	8000 PSI	.077	36,000 PSI
13/16	.8125	-13	8000 PSI	.092	36,000 PSI
15/16	.9375	-15	8000 PSI	.105	36,000 PSI

*Total of dynamic bending stress and axial stress due to internal pressure.

1/ Diameter tolerance for tubing 0.500 and under is + 0.003, -0.000.
Diameter tolerance for tubing 0.500 and under is + 0.003, -0.000.

2/ Tube wall thickness tolerance is +10%, -5%.

3.6 Fitting Over-Torque Requirements - All fittings requiring torque shall withstand the application of a torque 3 times the maximum specified for attachment and removal of fittings and lines, without permanent distortion or impairment of function.

3.7 Workmanship - Machined surfaces of fittings shall be free from burrs, longitudinal or spiral tool marks. Unless a finer finish is specified on applicable drawings, sealing surfaces shall be smooth, except that annular tool marks up to 100 microinches roughness height rating (RHR), as defined in USA B46.1 - 1962, will be acceptable. All other machined surfaces shall not exceed 125 RHR. Unmachined surfaces, such as forging surfaces and bar stock flats, shall be of uniform quality and condition, free from blisters, fins, folds, seams, laps, cracks, segregations, spongy areas, or other defects which would adversely affect their serviceability, and, except for forging parting lines, shall not exceed 250 RHR. Surface defects may be explored and if they can be removed so that they do not appear on re-etching and the required section thickness can be maintained, they shall not be cause for rejection.

3.3 Finish

3.3.1 Corrosion-Resistant Steel Fittings - Corrosion-resistant steel fittings and nuts shall be surface-treated in accordance with MIL-S-5002.

3.4 Identification of Product - All parts shall be identified in accordance with the instructions specified in 3.4.1, 3.4.2, and 3.4.3 (see 4.7.1)

3.4.1 Manufacturer's Trademark - Unless otherwise specified, all fittings and nuts shall be marked with the manufacturer's name or trademark.

3.4.2 Marking for Part Number and Size - A numerical equivalent to the dash number indicating size is optional. All fittings and nuts larger than 3/8-inch tube size shall be marked with the part number, exclusive of size.

3.4.3 Size, Method, and Location of Marking - Marking shall be accomplished by embossing or impression stamping on the fitting or nut in a location not detrimental to the part or to its corrosion protection.

3.5 Performance - The fitting and nut, when assembled to tubing specified in Table III, shall be capable of the performance specified in 3.5.1, 3.5.2, 3.5.3, and 3.5.4.

3.5.1 Pressure - The fitting shall be designed for an operating pressure of 8000 psi, a proof pressure of 16,000 psi and a burst pressure of 24,000 psi. The fittings shall withstand burst pressure without leakage or failure.

3.5.2 Impulse - Fittings of all materials shall be capable of 10,000,000 impulse cycles without leakage or failure.

3.5.3 Flexural Strength - The assembled material combinations shown in Table III shall withstand 10,000,000 cycles of flexure, without leakage or failure of the tube, fitting, or nut.

3.5.4 Repeated Assembly - Classes II and III fittings of all materials shall be capable of withstanding eight repeated assemblies, at both the minimum and maximum torque values, without leakage or indication of failure of the nut or fitting.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection - Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the procuring activity. The procuring activity reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Lot - A lot shall consist of all parts of a given part number made from the same batch of material and processed at the same time.

4.2.1 Record Maintenance - The supplier shall maintain a record of inspections applied to each lot.

4.2.2 Material Certification - Records of chemical composition analysis, mechanical property tests showing conformance to the applicable material specifications shall be made available to the procuring activity for each lot of fittings.

4.3 Classification of Inspections - The inspection and testinq of fittings and nuts shall be classified as follows:

(a) Qualification Inspection (4.4)
(b) Quality Conformance Inspection (4.5)

4.4 Performance Test

4.4.1 Samplinq Instructions - Performance test samples shall consist of the parts specified in Table IV for each size and material.

4.4.2 Tests - The following performance tests shall be conducted on the test samples as specified in Table IV.

4.4.3 Test Report, Test Samples, and Data for the Procurinq Activity. When the tests are conducted at a location other than the laboratory of the procuring activity, the following shall be available for furnishing to that activity:

a. Test report in accordance with MIL-STD-831, and shall include a report of all tests and outline description of test conditions.

b. Test samples that were tested and three untested samples of each size for which qualification is desired, if requested by the qualifying activity within one year subsequent to submittal of Qualified Products List request.

c. Engineering data in the form of detail and assembly drawings. The assembly drawings shall have a cut away section showing all details in their normal assembly position and shall carry part numbers of all details and subassemblies.

Table IV. Performance Test Samples 1/ 2/

Material	Applicable Test
3/	Burst Pressure(see 3.5.1 & 4.7.4)
3/	Impulse (see 3.5.2 & 4.7.3)
3/	Flexural Strength(see 3.5.3 & 4.7.5)
3/	Repeated Assembly (see 3.5.4 & 4.7.6)
3/	Grain Flow (Rolled Threads) (see 3.2.2.1 & 4.7.8)
4/	Quality conformance tests (a),(b),(c) & (d) of 4.5.2 (see 2/)

1/ All fittings specified shall be assembled with tubing specified in Table III.
2/ In each size and material desired.
3/ All materials as applicable. Test report must identify materials used.
4/ All samples subjected to performance tests shall be selected from a lot previously subjected to the specified quality conformance inspection ((a),(b),(c) and (d) of 4.5.2).

4.5 Quality Conformance Inspection

4.5.1 Sampling

4.5.1.1 Non-Destructive Tests - Sampling for material, threads, finish, dimensions, marking, surface defects, and workmanship shall be at random in accordance with MIL-STD-105 at an Acceptable Quality Level (AQL) of 4.0 percent.

4.5.1.2 Destructive Tests - Sampling for tests specified in (d), (e) and (f) of 4.5.2 shall be performed in accordance with MIL-STD-105, Inspection level S-1, acceptance number zero.

4.5.2 Inspection - Each individual lot of fittings and nuts shall be subjected to the following examination and tests:

(a)	Examination of product	(4.7.1)
(b)	Chemical composition	(4.2.2)
(c)	Physical properties	(4.2.2)
(d)	Hardness	(4.7.7)
(e)	Grain flow	(4.7.8)
(f)	Packaging, packing, marking	(4.9)

4.6 Rejection and Retest - Rejected lots shall be resubmitted for retest and acceptance in accordance with MIL-STD-105. Parts subjected to nondestructive tests and failing to conform to the requirements of these tests shall be rejected. Parts subjected to destructive tests shall be discarded.

4.7 Inspection Methods

4.7.1 Examination of Product - Each lot of fittings and nuts will be examined to determine conformance with this specification and the applicable drawing with respect to material, dimensions, threads, wall thickness, surface defects, finish, marking, and workmanship (see 3.1, 3.2, 3.3, 3.4, and 3.7).

4.7.2 General Testing Practice for Tests

4.7.2.1 Thread Lubricant - No thread lubricant shall be used other than hydraulic fluid conforming to MIL-H-83282 or MIL-H-46170, unless specifically approved by the procuring activity.

4.7.2.2 Tube Preparation - Tubes shall be prepared in accordance with the supplier's instructions.

4.7.2.3 Installation of Permanent Fittings - Class I permanent fittings shall be installed in accordance with the supplier's instructions.

4.7.2.4 Assembly of Separable Tube Fittings - Class II separable fittings shall be assembled on tubes in accordance with the supplier's instructions.

4.7.2.5 Installation of Separable Fittings - Class II separable fittings shall be installed in accordance with the supplier's instructions. All torque requirements shall be for lubricated threads and shall have a maximum and minimum value.

4.7.2.6 Installation of Port Fittings - Class III fittings shall be installed in accordance with the supplier's instructions. The instructions shall include boss preparation. All torque values shall be for lubricated threads and shall have a maximum and minimum value.

4.7.2.7 Test Fluid - Fluid conforming to MIL-H-83282 or MIL-H-46170 shall be used in all tests.

4.7.3 Impulse - Three samples each of elbows and tees shall be mounted on tubing of the type designated in Table III for the fitting materials under test. The tube assembly shall be joined with minimum torque values if applicable and subjected to the following tests:

The assembly shall first be tested at proof pressure for 5 minutes to verify that the requirements of 3.5.1 are met. Impulse testing shall then be performed in such a manner to meet the wave shape requirements of Figure 2(a) or 2(b). The operating temperature shall be 400°F. Fittings shall complete 10,000,000 impulse cycles to verify that the requirements of 3.5.2 are met, after which they shall again be tested at proof pressure for 5 minutes (see Figure 2 to verify no leakage).

4.7.4 Burst Pressure - For qualification, elbows, and tees, shall be used in this test. Fittings shall be assembled so that at least 8 inches of free tubing extends between the two end fittings. One-half the samples shall be assembled with maximum torque if applicable. Pressure shall be raised to the proof pressure for 5 minutes. Pressure shall then be increased at a rate of 20,000 ± 5,000 psi per minute to the burst pressure, as specified in 3.5.1, or until failure or leakage occurs; no failure or leakage shall occur at a pressure less than the specified burst pressure. (See Table IV). For quality conformance tests, only fittings of part number being furnished need to be tested, in which case the tube, or nut, may be omitted and a suitable adapter substituted.

4.7.5 Flexural Strength - The flexure test may be performed in one of the two methods are shown on Figures 3 and 4. All fittings must perform to the method shown in Figure 5. Any method may be used, provided that the stress is imposed and measured at a point adjacent to the fitting under test. Two specimens shall be tested at the stress level indicated on Table III. The remaining specimens shall be tested at higher stress levels in order to obtain an S/N curve. The stress level measured shall include tensile bending stress plus the axial tension due to pressure. Measurement of the stress shall be obtained by placing two strain gages, 180 degrees apart, on the periphery of the tube in the plane of maximum stress. The center of the strain gage shall be placed 3/16 ± 1/64 inch from the tail of the sleeve. During the test, a constant pressure equal to the operating pressure, noted in 3.5.1, shall be imposed. Frequency of flexing may be any rate from 30 to 500 cycles per second, depending upon method selected. The specimens shall be assembled with maximum torque values, if applicable. Duration of test shall be 10,000,000 cycles or until prior failure or leakage occurs.

4.7.5.1 Cantilever Beam Method - Figure 3 shows one method, wherein the flexural requirements are obtained by imposing a concentrated load on the free swiveling end of the tube assembly. The opposite end (test fitting) is rigidly supported in a fixture capable of varying the tube length to obtain the desired stress level in the tube. The motion of the free end may be either rotary or

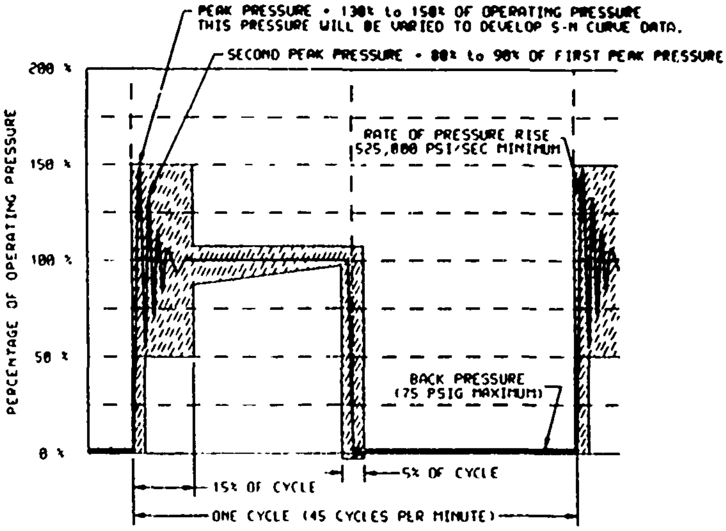


Figure 2(a) DAMPED WAVE

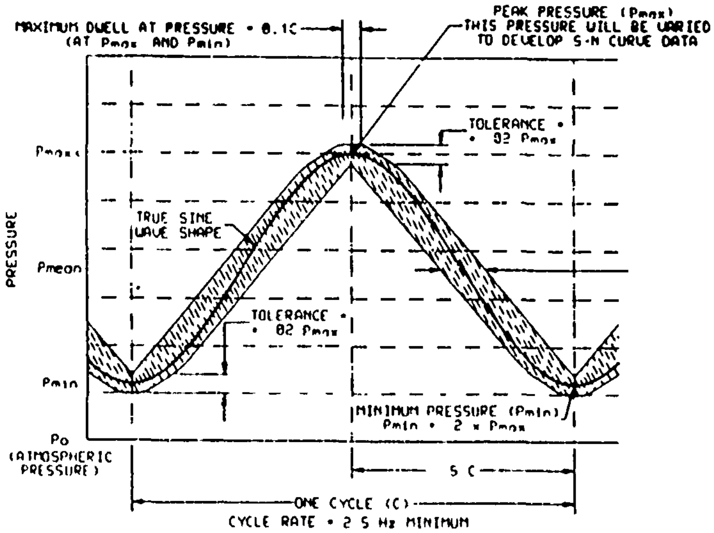


Figure 2(b) SINE WAVE

FIGURE 2. PRESSURE IMPULSE WAVE SHAPES

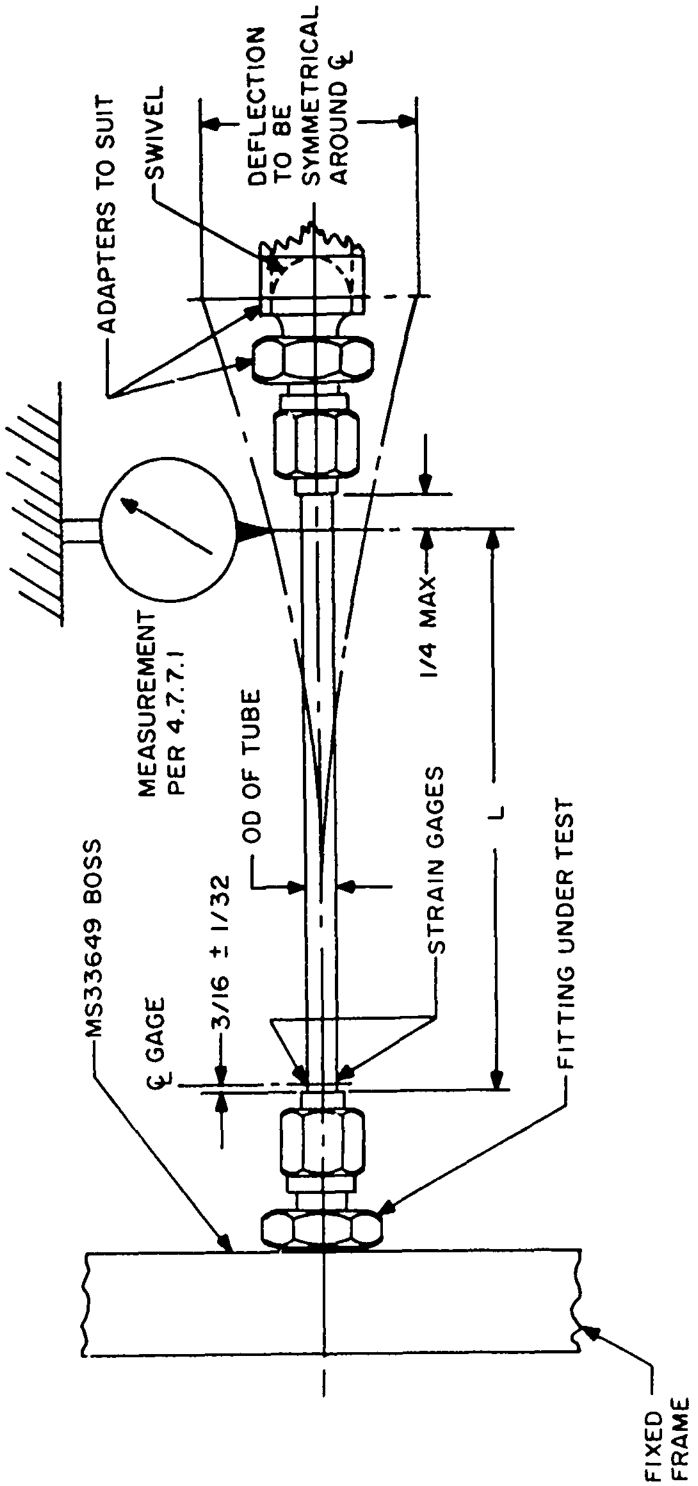


FIGURE 3. CANTILEVER BEAM METHOD

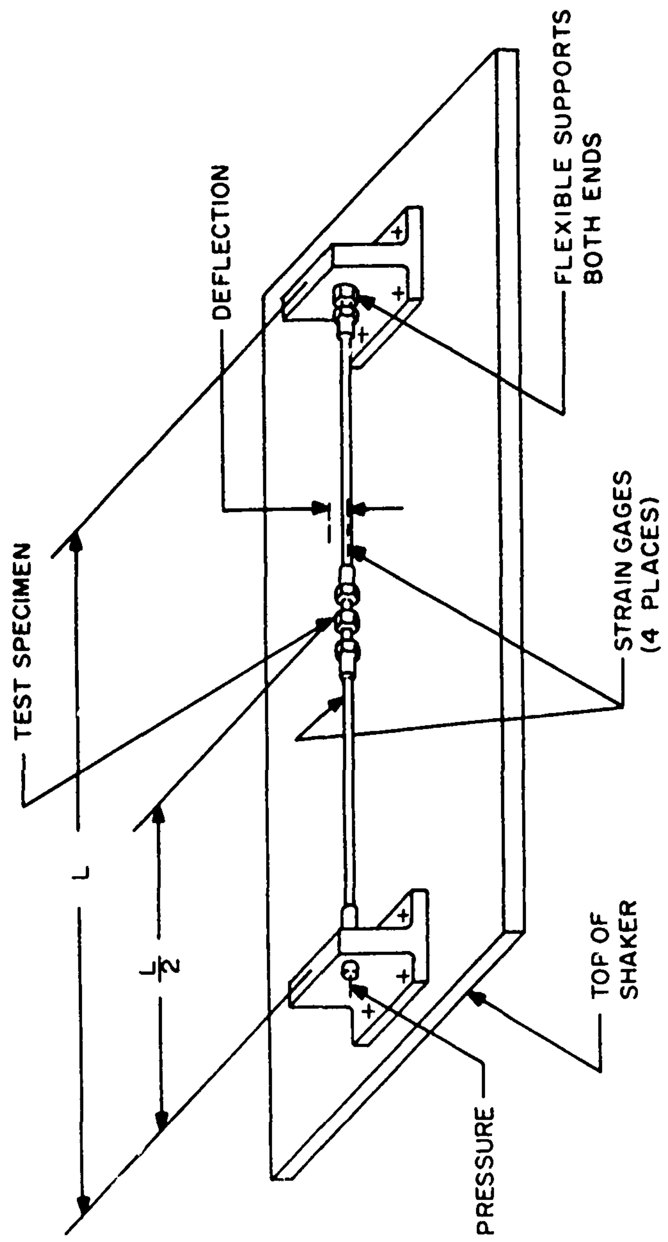


FIGURE 4. SIMPLE BEAM METHOD

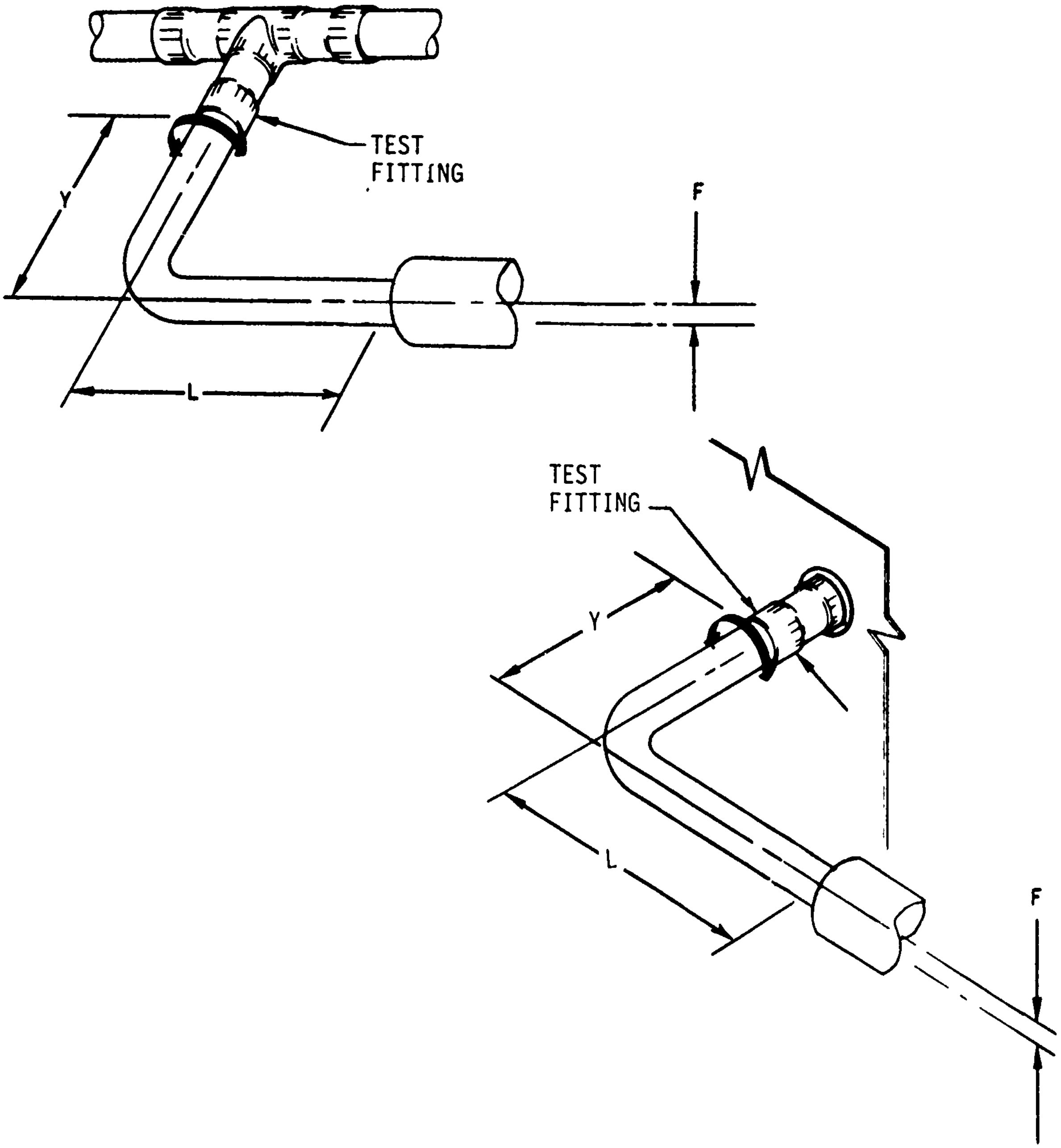


FIGURE 5. TORSION METHOD

planar. Tube length "L" shall be determined by actual stress measured. Tentative length may be calculated, however, from the following formula:

$$L = \sqrt{\frac{3\ DEC}{S}}$$

in which L = length in inches from strain gage to point of deflection
D = displacement in inches
E = modulus of elasticity (30,000,000 for corrosion-resistant steel)
C = one-half tube outside diameter (inches)
S = stress in tube (see Table III) (at strain gage)
F = applied force

The above formula was derived by combining the following formulae:

$$S = \frac{MC}{I} = \frac{FLC}{I}$$

$$D = 1/3\ \frac{FL^3}{EI}$$

4.7.5.2 Simple Beam Method - Figure 4 shows another method, wherein the test arrangement is essentially a simple beam, with a concentrated load (test fitting weight times acceleration) at the center mounted on a "shaker". Both supports provide free swivelling action. In order to eliminate side loads on the shaker table, it is recommended that the static pressure be applied to both ends of the test specimen. Total length of the test specimen "L" shall be determined by actual stress measured. Tentative length "L" may be calculated, however, from the following formula:

$$L = \sqrt{\frac{12\ DEC}{S}}$$

in which L = total length in inches
D = displacement at center in inches
E = modulus of elasticity
C = one-half tube outside diameter (inches)
S = stress in tube (see Table III) (at strain gage)

NOTE: Displacement (D) is a function of weight of tube union times acceleration imposed. Acceleration should be varied to obtain desired displacement (stress).

4.7.5.3 Torsion Method - Figure 5 shows a method wherein the flexural requirements are obtained by imposing a concentrated load on the free end of the tube assembly. The opposite end (test fitting) is rigidly supported in a fixture to obtain the desired stress level (combined torsion and bending) in the tube. The lever arm and distance to the fitting may be calculated from the following formula:

$$LY = \frac{DGJ}{FL}$$

in which L = lever arm in inches
Y = distance to fitting in inches
D = deflection in inches
G = modules of elasticity in shears (IN^2)
J = polar moment of inertia (IN^4)
F = applied force

4.7.6 <u>Repeated Assembly for Separable Fittings</u>

4.7.6.1 <u>Minimum Tightening</u> - The tube and fitting assembly shall be assembled and disassembled eight successive times, using minimum torque values. Each repeated assembly operation shall include the assembly and complete removal of the tube from the fitting body and reassembly 90 degrees out of previous tube-to-fitting phase relationship. After each third and final tightening operation, the assembly shall be subjected to the proof pressure for 5 minutes. After the eighth tightening operation, the assembly shall be subjected to the burst pressure test of 4.7.4.

4.7.6.2 <u>Maximum Tightening</u> - The test specified in 4.7.6.1 shall be performed, using new assemblies, with the maximum torque values.

4.7.7 <u>Hardness</u> - Hardness readings shall be taken on a smooth flat surface of any unthreaded portion of the fitting or nut.

4.7.8 <u>Grain Flow in Threads</u> - Grain flow in rolled threads shall be determined by macroexamination. Specimens shall be taken from the finished part by sectioning on a longitudinal plane across the threaded area. The specimen shall be etched in an aqueous solution containing 50 percent (by volume) of commercial hydrochloric acid at 160° to $180^{\circ}F$ for sufficient time to reveal the macrostructure adequately.

5. PREPARATION FOR DELIVERY

5.1 Preservation and Cleaning

5.1.1 Preservation - No preservative compound shall be applied to the fittings.

5.1.2 Cleaning - Before packaging, all parts shall be free from grease, oil, dirt, or any other foreign matter.

6.0 NOTES

6.1 Intended Use - Fittings covered by this specification are intended for use in aeronautical fluid systems (see 1.1).

6.2 Ordering Data - Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Part Number required (see 1.2 and 3.2).
(c) Applicable levels of preservation, packaging, and packing (see 5.0).

PREPARED BY		NUMBER
D. E. Blanding	**Rockwell International Corporation** **North American Aircraft Operations**	L278C8001
APPROVALS		TYPE
[illegible signature] 2/5/87	# SPECIFICATION	DATE 20 January 1987
		SUPERSEDES SPEC. DATED:
	FSCM NO. ________	REV. LTR. / PAGE 1 of 15

TITLE

JOINT, SWIVEL, HYDRAULIC, 8000 PSI, AIRCRAFT

FORM NAO 131 H-1 REV 10-81

(█ - IND... CHANGE)

1. SCOPE

1.1 Scope. This specification covers the requirements for swivel joints used in 8000 psi aircraft lightweight hydraulic systems.

1.2 Classification. Swivel joints covered by this specification shall be of the following types:

	Swivel Motion
STYLE A	Single plane
STYLE B	Axial angularity
STYLE C	Linear, dual plane, other special motions

2. APPLICABLE DOCUMENTS

2.1 Issues of Documents. The following documents of the issue in effect on date of invitation for bids or request for proposal form a part of this specification to the extent specified herein.

2.1.1 Government Documents

SPECIFICATIONS

Military

MIL-C-5501 - Cap and Plug, Protective, Dust and Moisture Seal

MIL-H-6083 - Hydraulic Fluid, Petroleum Base, for Preservation and Testing

MIL-H-83282 - Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft

MIL-J-5513C - Joints, Hydraulic Swivel

MIL-P-116 - Preservation, Method of

STANDARDS

Military

MIL-STD-129 - Marking for Shipment and Storage

MIL-STD-794 - Parts and Equipment Procedures for Packaging and Packing of

MIL-STD-810 - Environmental Test Methods

MIL-STD-831 - Test Report, Preparation of

2.1.2 Rockwell Documents

L273C8003 Fittings, Fluid Connection, Aircraft, 8000 PSI

2.2 Other Publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

SOCIETY OF AUTOMOTIVE ENGINEERS

AIR 1362 Physical Properties of Hydraulic Fluids

3. REQUIREMENTS

3.1 Design and Construction. The swivel joint shall be designed in accordance with MIL-J-5513C to conduct pressurized fluid between hydraulic components having limited relative motion. The swivel joint design may be either pressure balanced or unbalanced. Standard Packings and gland designs shall incorporate the use of dual seals. Non-standard packings and gland designs may be used subject to approval by the procuring activity.

3.1.1 Design Goals. The swivel design shall provide improved reliability and maintainability. Dual seals shall be considered.

3.1.2 Fitting Ends. End fittings for the swivel assemblies shall be the detachable type conforming to L273C8003 Type III.

3.2 Performance Characteristics.

3.2.1 Immersion. The swivel joint shall meet all performance requirements specified herein after being immersed in hydraulic fluid conforming to MIL-H-83282 at 400°F for a duration of 72 hours.

3.2.2 Pressures.

3.2.2.1 Rated Pressure. The rated operating pressure shall be 8000 psig.

3.2.2.2 Proof Pressure. The swivel joint shall withstand a proof pressure of 12,000 psig at 400°F without permanent deformation or external leakage, and shall function satisfactorily when the pressure is reduced to 8000 psig.

3.2.2.3 Burst Pressure. The swivel joint shall withstand a burst pressure of 24,000 psig at 400°F without failure.

3.2.3 Rated Flow. Rated flow through the swivel joint shall be as specified in Table I.

TABLE I. Rated Flow

Dash No.	size, O.D., In.	Rated flow, gpm
-3	3/16	
-5	5/16	
-7	7/16	TBD
-9	9/16	
-11	11/16	
-13	13/16	
-15	15/16	

3.2.4 Pressure Drop. Pressure drop with rated flow applied shall not exceed 15 psig for straight through swivel joints and 30 psig for swivel joints with one 90° bend.

3.2.5 Leakage. The swivel joint shall have no external leakage with low pressure (5 to 10 psig) or with rated pressure applied at temperatures from -65° to +400°F. The swivel joint shall have no reverse leakage with 25 inches of Hg vacuum applied.

3.2.6 Swiveling Torque. The breakout torque required to rotate or move the swivel joint with rated pressure applied shall not exceed the applicable value specified in Table II.

TABLE II. Maximum Allowable Breakout Torque

Dash Size	Style A Swivel, lb-in	Style B Swivel, lb-in	Style C Swivel, lb-in
-3			
-5			
-7			
-9	TBD	TBD	TBD
-11			
-13			
-15			

3.2.7 Endurance. The swivel joint shall withstand not less than 100,000 swiveling cycles with eccentric loading and 10,000,000 pressure impulse cycles.

3.3 Environmental Requirements

3.3.1 Temperatures. The swivel joints shall operate without binding or other malfunction during exposure to temperatures from -65 to +400°F.

3.3.2 Icing. The swivel joint breakout torque shall not exceed the applicable value specified in Table II during exposure to icing conditions.

3.3.3 Vibration. The swivel joint shall withstand random vibration of $1.0g^2/Hz$ over the range of 300 to 1000 Hz.

3.3.4 Shock. The swivel joint shall withstand sawtooth impact shocks up to 20g for durations of not less than 0.011 seconds.

3.3.5 Dust. The swivel joint breakout torque shall not exceed the applicable value specified in Table II following exposure to dust laden air.

3.4 Dimensions. The swivel joint dimensions and tolerances shall be specified by the supplier.

3.5 Weight. The swivel joint shall be the lightest weight consistent with good design that is capable of meeting the requirements of this specification.

3.6 Item Marking. The swivel joint shall be marked for identification in accordance with MIL-STD-130.

3.7 Workmanship. Workmanship shall be of high quality that will insure proper operation and service life of the swivel joint.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements specified herein. Except as otherwise specified in the contract, the contractor may utilize his own facilities or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the procuring activity. The procuring activity reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of Inspections. The inspection requirements specified herein are classified as follows:

a. Performance tests (see 4.4)
b. Quality conformance inspections (see 4.5)
c. Packaging inspection (see 5.0)

4.3 Inspection Conditions.

4.3.1 Test Fluid. The hydraulic fluid used for all inspections shall conform to MIL-H-83282 or MIL-H-6083.

4.3.2 Temperatures. Unless otherwise specified, all inspections shall be conducted at a room temperature of +70° to +90°F and a fluid temperature of +70 to 130°F. Unless otherwise specified, tests conducted at extreme temperature shall be performed with the swivel joint and fluid stabilized at the test temperature.

4.4 Performance Test. Performance tests shall be as specified in Table III. The sequence of testing shall be as listed in Table III.

TABLE III. Performance Tests

Test	Requirement Paragraph	Test Method Paragraph
Examination of product	3.2, 3.4 thru 3.7	4.7.1
Immersion test	3.2.1	4.7.2
Proof pressure test	3.2.2.2	4.7.3
Leakage tests	3.2.5	4.7.4
Pressure drop test	3.2.4	4.7.5
Swiveling torque test	3.2.6	4.7.6
Low temperature test	3.3.1	4.7.7
Vibration test	3.3.3	4.7.8
Shock test	3.3.4	4.7.9
Endurance	3.2.7	4.7.10
Burst test	3.2.2.3	4.7.11

4.4.1 Test Report, Test Samples and Data for the Procuring Activity. When the tests are conducted at a location other than the laboratory of the procuring activity, the following shall be available for furnishing to that activity:

a. Test report in accordance with MIL-STD-831, and shall include a report of all tests and outline description of test conditions.

b. Test samples that were tested and three untested samples of each size for which qualification is desired, if requested by the qualifying activity within one year subsequent to submittal of Qualified Products List request.

c. Engineering data in the form of detail and assembly drawings. The assembly drawings shall have a cut-away section showing all details in their normal assembly position and shall carry part numbers of all details and subassemblies.

4.5 Quality Conformance Inspections. Each swivel joint to be furnished under contract shall be subjected to the quality conformance inspections of Table IV.

TABLE IV. Quality Conformance Inspection

Inspection	Requirement Paragraph	Test Method Paragraph
Examination of product	3.2, 3.4 thru 3.7	4.7.1
Proof pressure test	3.4.2.2	4.7.3
Leakage tests	3.4.5	4.7.4

4.6 Packaging Inspection. The inspection of the preservation-packaging and interior package marking shall be in accordance with the applicable group quality conformance inspection requirements of MIL-P-116. The inspection of the packing and marking for shipment and storage shall be in accordance with the quality assurance provisions of the applicable packing specification for the proper level and the marking requirements of MIL-STD-129.

4.7 Methods of Examination and Test.

4.7.1 Examination of Product. The swivel joint shall be examined to determine compliance with the requirements of this specification with respect to materials, dimensions, marking, and workmanship.

4.7.2 Immersion Test. The swivel joint shall be immersed continuously in hydraulic fluid for a period of 72 hours at a temperature of 400 ± 5°F. All internal parts of the swivel joint shall be in contact with the fluid. After this 72-hour period, the swivel joint shall be subjected to the proof pressure test of 4.7.3 immediately or remain in the fluid at room temperature until ready for test.

4.7.3 Proof Pressure Test. The proof pressure test shall be conducted at +400 ± 5°F for the performance test, and at room temperature for the quality conformance inspection. A hydrostatic pressure of 12,000 +100/-0 psig shall be applied to the swivel joint and maintained for a period of two minutes. During this two-minute period, the joint shall be swiveled to four approximately equidistant positions through its swiveling cycle and held for approximately 30 seconds at each position. The swivel joint shall meet the requirements specified in 3.4.2.2.

4.7.4 Leakage Tests.

4.7.4.1 Low Pressure. The leakage test shall be conducted at 400 ± 5°F for the performance test, and at room temperature for the quality conformance inspection. A hydrostatic pressure of 5 to 10 psig shall be applied and trapped in the swivel joint by means of a shut-off valve. The 5 to 10 psig pressure shall be maintained for a period of two minutes during which time the swivel shall be operated 20 cycles through approximately 90 percent of its design travel. Leakage shall be indicated by loss of pressure or by external fluid loss. The swivel joint shall meet the requirements of 3.4.5.

4.7.4.2 Rated Pressure. The leakage test shall be conducted at 400 ± 5°F for the performance test, and at room temperature for the quality conformance inspection. A hydrostatic pressure of 8000 ± 100 psig shall be applied to the swivel joint for a period of two minutes during which time the swivel shall be operated 20 cycles through approximately 90 percent of its design travel. The swivel joint shall meet the requirements of 3.4.5.

4.7.4.3 Reverse Pressure. The reverse pressure leakage test shall be conducted for the performance test only, and shall be performed at room temperature. A vacuum equivalent to 25 inches of Hg shall be applied and trapped in the swivel joint by means of a shut-off valve. The 25 inches of Hg vacuum shall be maintained for a period of five minutes during which time the swivel shall be operated 25 cycles through approximately 90 percent of its design travel. Leakage shall be indicated by loss of vacuum. The swivel joint shall meet the requirements of 3.4.6.

4.7.5 Pressure Drop Test. The pressure drop test shall be conducted at 8000 $\pm$ 100 psig with a fluid temperature of +120 $\pm$ 5°F. A differential pressure gage shall be installed across the swivel joint. Flow at rated pressure shall be measured at return pressure with allowances for fluid density and temperature changes due to pressure. Rated flow as specified in Table I shall be passed through the swivel joint. The pressure drop in the swivel joint shall be considered to be the difference between (1) the drop through the swivel joint and connecting tubing and (2) the drop through a single straight tube used to replace the swivel joint and connecting tubing. The pressure drop shall not exceed the applicable limit specified in 3.4.4.

4.7.6 Swiveling Torque Test. The swiveling torque test shall be conducted at room temperature and at +400 $\pm$ 5°F. Rated pressure shall be applied to the swivel joint and maintained for five minutes. Following this five minute period, increasing torque shall be applied gradually to rotate or move the swivel. The breakout torque shall not exceed the applicable value specified in Table II.

4.7.7 Low Temperature Test. The swivel joint shall be filled with hydraulic fluid and a pressure of 5 to 10 psig applied at room temperature. The swivel joint shall then be cooled to -60 +0/-5°F and held at -65°F with 5 to 10 psig pressure for a minimum of 24 hours. Following this 24-hour period and while at -65°F, the breakout torque required to rotate or move the swivel shall be determined, with 5 to 10 psig, then with rated pressure applied. The breakout torque shall not exceed the applicable requirement specified in 3.4.6. Following the breakout torque test and while at -65°F, the joint shall be swiveled for 25 cycles through approximately 90 percent of its design travel, first with 5 to 20 psig, then with rated pressure applied. The swivel joint shall meet the requirements of 3.4.5 and 3.5.1. The swivel joint shall then be warmed rapidly from -65°F to at least +65°F. At intervals of approximately 20° and without temperature stabilization, the joint shall be swiveled through approximately 90 percent of its design travel, first with 5 to 20 psig, then with rated pressure applied. The swivel joint shall meet the requirements of 3.4.5 and 3.5.1.

4.7.8 Vibration Test. The swivel joint shall be vibration tested in accordance with MIL-STD-810, method 514.2, Procedure IA. The swivel joint shall be mounted in a setup similar to that shown on Figure 1. A hydrostatic pressure of 8000 $\pm$ 100 psig shall be applied to the swivel joint during the vibration test. Following the vibration test, the swivel joint shall be subjected to the leakage tests specified in 4.7.4.1 and 4.7.4.2 except the tests shall be performed at room temperature

4.7.9 Shock Test. The swivel joint shall be shock tested in accordance with MIL-STD-810, method 516.2, Procedure I. The swivel joint shall be mounted in a setup similar to that shown on Figure 1. A hydrostatic pressure of 8000 ± 100 psig shall be applied to the swivel joint during the shock test. Following the shock test, the swivel joint shall be subjected to the leakage tests specified in 4.7.4..1 and 4.7.4.2 except the tests shall be performed at room temperature.

4.7.10 Endurance Test. The endurance test shall consist of:

a. 100,000 swivel cycles (see 4.7.10.1)
b. 10,000,000 pressure impulse cycles (see 4.7.10.1)
c. Eccentric loading (see 4.7.20.3)
d. Dust laden air (see 4.7.10.4)
e. Icing conditions (see 4.7.10.5)

The following schedule of tests shall be repeated five times.

Step 1. 10,000 swivel and 15,000 impulse cycles with eccentric loading

Step 2. Dust test (see 4.7.10.4)

a. First, second, fourth and fifth schedule runs shall be modified dust test.
b. Third schedule run shall be complete dust test.

Step 3. 10,000 swivel and 15,000 impulse cycles with eccentric loading

Step 4. Icing test.

The swivel/impulse cycling shall be conducted at +400 ± 5°F. Maximum allowable external leakage shall be one drop per 100 cycles. No packing change shall be permitted during the endurance test. Following the endurance test, the swivel joint shall be subjected to the leakage tests specified in 4.7.4.1 and 4.7.4.2.

4.7.10.1 Swivel Cycling. A typical swivel cycling setup is depicted on Figure 2. The cycling rate shall be 25 ± 4 cpm. For style A type swivel joints (see 1.2), each half cycle shall consist of 120° rotation minimum. For B type swivel joints, each half cycle shall consist of 120° rotation minimum with a concurrent conical motion of 120° minimum (see Figure 3). Cycling requirements for style C type swivel joints shall be established by the procuring activity.

4.7.10.2 Pressure Impulse Cycling. Impulse pressure conforming to the curve shown in Figure 4(a) or 4(b) shall be applied to the inlet manifold at a rate not below the minimum specified. Electronic measuring equipment shall be used to monitor the wave form. The test fluid shall be MIL-H-83282.

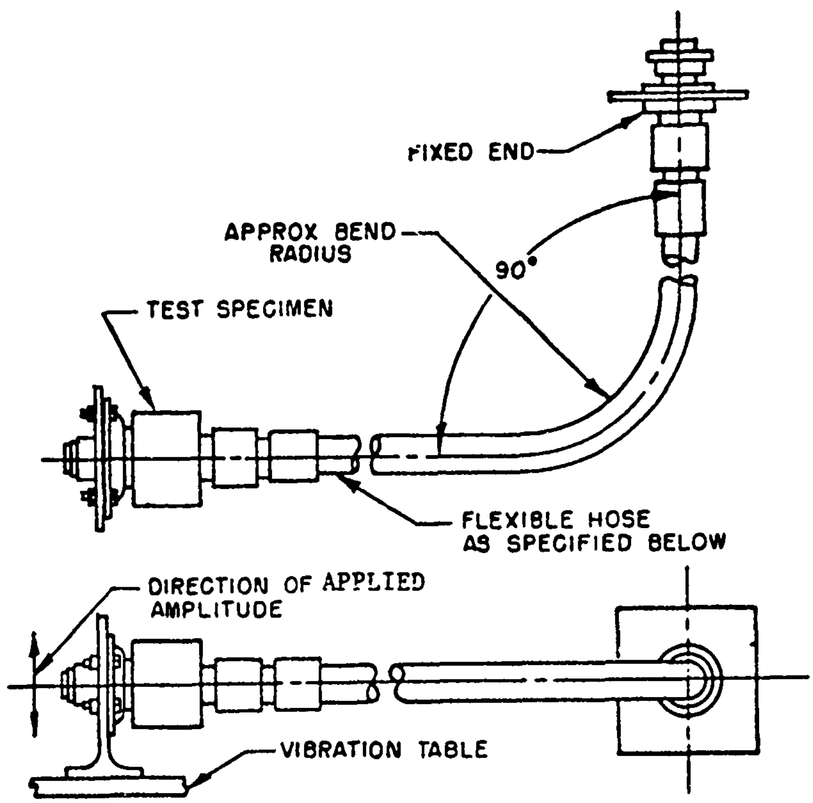


FIGURE 1. Typical Set-up for Vibration and Shock Test

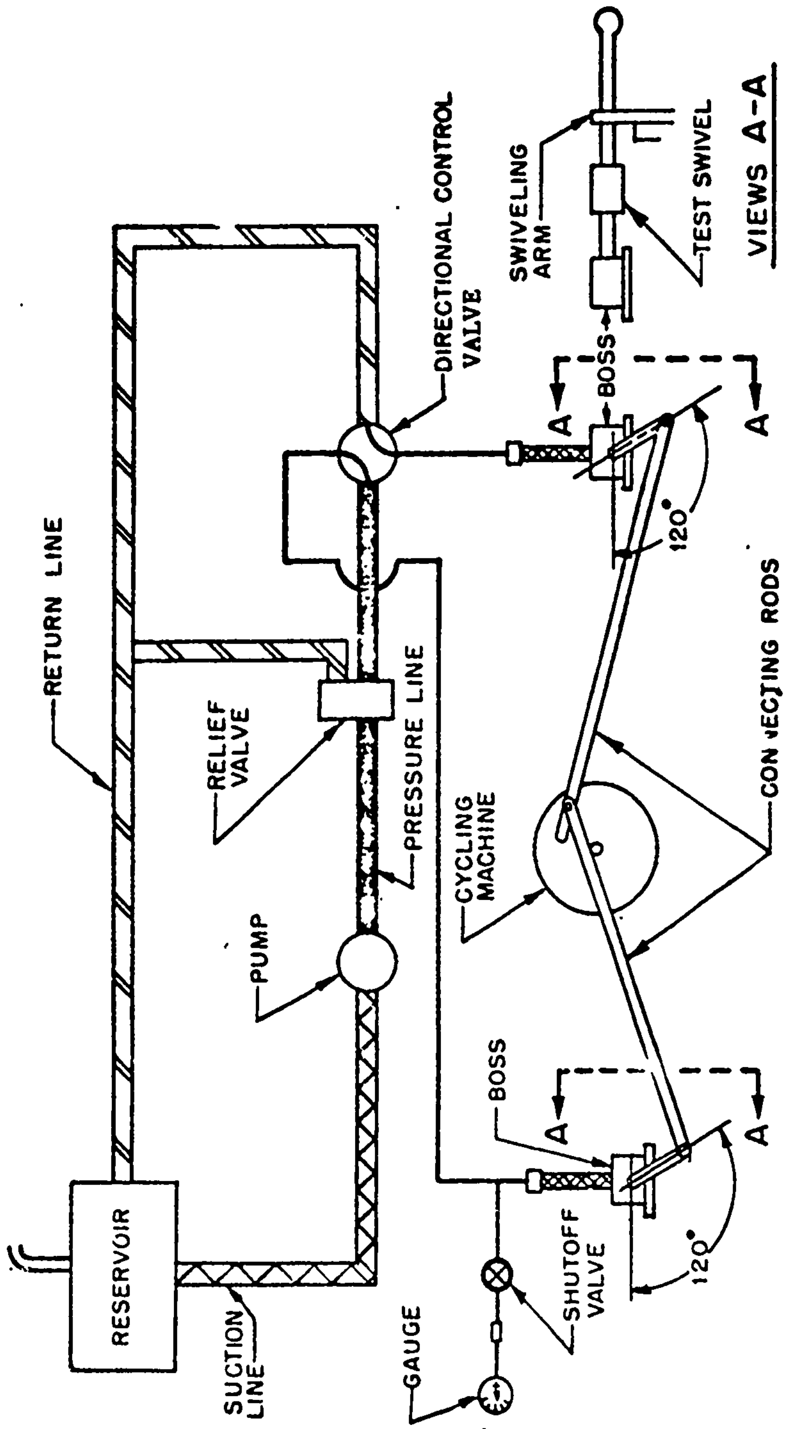


FIGURE 2. Typical Endurance Test Setup

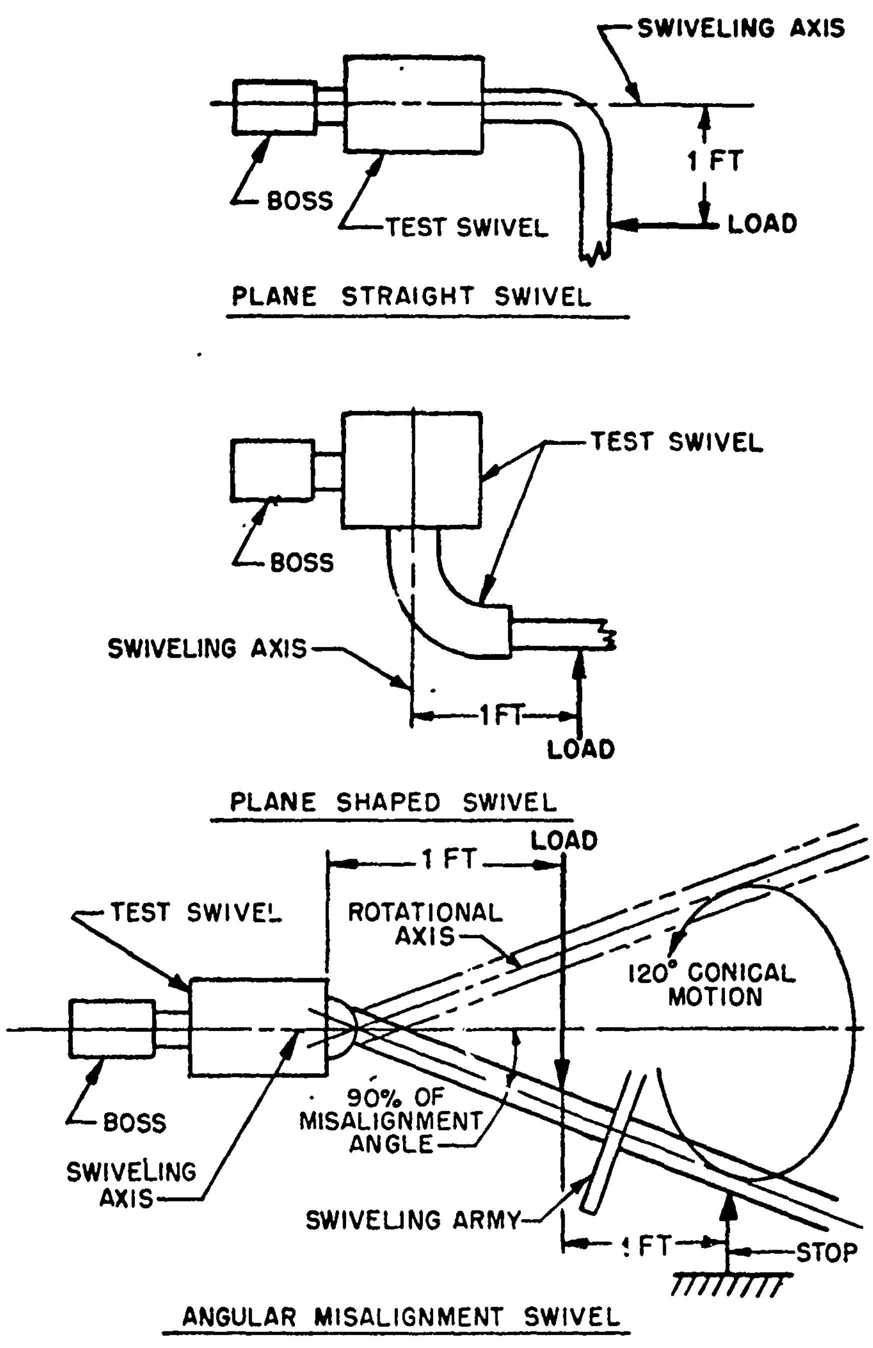


FIGURE 3. Eccentric Loading for Swivel Joints

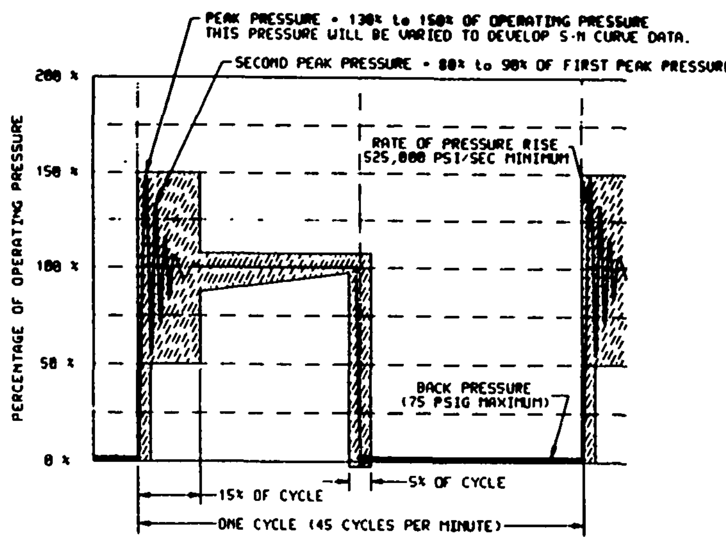


Figure 4(a) Damped Wave

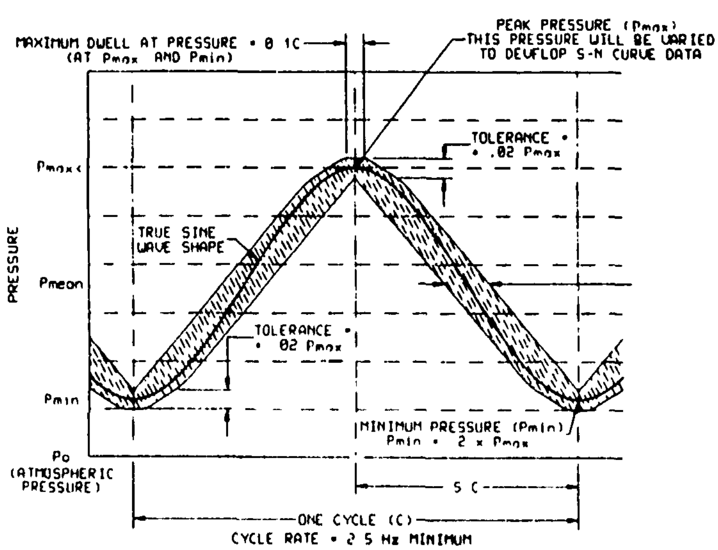


Figure 4(b) Sine Wave

FIGURE 4. Pressure Impulse Envelope

4.7.10.3 Eccentric Loading. Style A and B type swivel joints (see 1.2) shall be loaded eccentrically as shown on Figure 3. The load shall be applied during the swivel cycling specified in 4.6.10.1 and the magnitude shall be as specified in Table V. The load direction shall be reversed after completion of each block of 10,000 cycles.

TABLE V. Eccentric Loads.

Dash Size	Load, lb -0%, +10%
-3	
-5	
-7	
-9	TBD
-11	
-13	
-15	

4.7.10.4 Dust Test. The dust test shall conform to MIL-STD-810, Method 510.1, Procedure I for the third schedule run in Step 2 as specified in 4.7.10. The dust test procedure shall be modified for the first, second, fourth, and fifth schedule runs of Step 2. The modified dust test shall conform to MIL-STD-810, Method 510.1, Procedure I except that Step 1 (of Procedure I) only shall be conducted and the time duration shall be one hour in lieu of six hours. The swivel joint shall be filled with hydraulic fluid and pressurized to 5 to 10 psig during the dust exposure periods.

4.7.10.5 Icing Test. The swivel joint shall be placed in a temperature chamber and stabilized at +35 ± 2°F. With the swivel joint oriented so that the axis of rotation is horizontal, the swivel joint shall be fully immersed in a mixture of water and ice at +32°F for one minute. Following this 1-minute period, the swivel joint shall be removed from the water and the chamber temperature decreased to 15 ± 5°F within five minutes and maintained at +15°F for 30 minutes. No hydraulic pressure or swiveling motion shall be applied to the swivel joint during this 30-minute period. Following the 30-minute period and while at +15°F, a hydrostatic pressure of 5 to 10 psig shall be applied to the swivel joint. The 5 to 10 psig pressure and +15°F temperature shall be maintained for one hour. Following this 1-hour period and while at +15°F, the breakout torque required to rotate or move the swivel shall be determined with 5 to 10 psig, then with rated pressure applied. The breakout torque shall not exceed the requirements specified in 3.5.2.

4.7.11 Burst Pressure Test. The burst pressure test shall be performed at a temperature of +400 ± 10°F. Hydrostatic pressure shall be applied to the swivel joint at a rate of 20,000 ± 5000 psig per minute until a pressure of 24,000 +100, -0 psig is reached. This burst pressure shall be held for two minutes. The swivel joint shall meet the requirements specified in 3.4.2.3.

5. PACKAGING

5.1 Preservation-packaging. The preservation-packaging and interior package marking shall be in accordance with the applicable group quality conformance inspection requirements of MIL-P-116. The inspection of the packing and marking for shipment and storage shall be in accordance with the quality assurance provisions of the applicable packing specification for the proper level and the marking requirements of MIL-STD-129. All openings shall be sealed with metal caps or plugs conforming to MIL-C-5501.

6. NOTES AND CONCLUDING MATERIAL

6.1 Intended Use. The swivel joints covered by this specification are intended for use in aircraft 8000 psi hydraulic systems.

6.2 Ordering Data. The contract should specify the following:

a. Title, number, and date of this specification to be followed.

b. Style required (see 1.2).

c. Levels of preservation-packaging and packing (see 5.0).

PREPARED BY		NUMBER
D. E. Blanding	Rockwell International Corporation North American Aircraft Operations	L276C8002
APPROVALS		TYPE
J. A. Schmidt 2/5/87	**SPECIFICATION**	DATE 20 January 1987
		SUPERSEDES SPEC. DATED:
	FSCM NO. ______	REV. LTR. / PAGE 1 of 16

TITLE

COUPLING, QUICK DISCONNECT, SELF SEALING, HYDRAULIC, 8000 PSI, AIRCRAFT

FORM NAO 131-H-1 REV 10-81 (▌- INDICATES CHANGE)

1. SCOPE

1.1 Scope. This specification covers the requirements for hydraulic self-sealing quick disconnect couplings for use in 8000 psi aircraft lightweight hydraulic systems.

1.2 Classification. Couplings covered by this specification shall be an assembly consisting of a mounting half and an attaching half of the following types:

Type I — In-line installation: male lip seal.

Type II — In-line port installation: end threads conforming to AS 930 on mounting half and male lip seal.

Type III — Ground service installation: end threads conforming to MS 33515 on bulkhead mounting half except the internal recess for the tube connection shall be omitted.

1.3 Sizes. Coupling sizes covered by this specification are:

Dash No.	Equivalent tube size, O.D., In.	Rated flow, gpm
-3	3/16	
-5	5/16	
-7	7/16	
-9	9/16	TBD
-11	11/16	
-13	13/16	
-15	15/16	

2. APPLICABLE DOCUMENTS

2.1 Issues of Documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1.1 Government Documents

SPECIFICATIONS

Military

MIL-C-5501 - Cap and Plug, Protective, Dust and Moisture Seal

MIL-C-25427 - Quick Disconnect, Hydraulic

MIL-E-5272 - Environmental Testing, Aeronautical and Associated Equipment, General Specification for

STANDARDS

<u>Military</u>

MIL-H-83282 - Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft

MIL-P-116 - Preservation, Methods of

MIL-STD-129 - Marking for Shipment and Storage

MIL-STD-130 - Identification Marking of U.S. Military Property

MIL-STD-794 - Parts and Equipment Procedures for Packaging and Packing of

MIL-STD-8314 - Test Reports, Preparation of

MS33515 - Fitting End, Standard Dimensions for Bulkhead Flareless Tube Connection

2.1.2 <u>Rockwell Documents</u>

L273C8003 Fittings, Fluid Connection, Aircraft, 8000 PSI

2.2 <u>Other Publications</u>. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the effect on date of invitation for bids or request for proposal shall apply.

Society of Automotive Engineers

AS 930 - Fitting End, Straight Thread, Boss Connection

3. REQUIREMENTS

3.1 <u>Design and Construction</u>. The coupling shall consist of two mating halves, and when installed in a hydraulic system, shall require a single simple hand motion to connect or disconnect a line without tools. It shall be possible to determine visually and by touch whether the coupling is locked or unlocked. There shall be no stable, partially connected position permitting fluid to flow. Coupling halves of a given size shall be interchangeable as an assembly. It shall be impossible to interconnect coupling halves of different sizes. It shall be impossible to connect a coupling rated for service at 8000 psi with one rated for use at other pressures (e.g., 3000 psi).

The coupling shall permit unrestricted fluid flow in either direction under any allowable flow or pressure surge condition. Coupling and uncoupling operations shall be possible with 100 psig static pressure applied to both halves of the coupling. Coupling and uncoupling with rated pressure applied shall not be required. The coupling shall be designed to restrict the introduction of air, dirt, and moisture into the hydraulic system during the coupling/uncoupling

operation. Dust covers shall be per MIL-C-25427. The coupling shall also act as a redundant seal to prevent loss of fluid from the aircraft when the ground half is uncoupled. Standard packings and gland designs shall be utilized to the maximum extent possible.

3.1.1 Design Goals. The quick disconnect design shall provide improved reliability and maintainability. Dual seals shall be considered.

3.1.2 Flange. A removable flange for fastening the mounting half of Types I, II, and III couplings to a bulkhead shall be provided as required by the procuring activity.

3.1.3 Flange Strength. The flange of 3.1.1 shall withstand 1.5 times the maximum wrenching torque for the mating fittings.

3.1.4 Fitting Ends. End fittings for the quick disconnect assembly shall be the detachable type conforming to L273C8003 Type III.

3.1.5 Protective Covers. Automatic dust caps and plugs shall be provided, as required by the procuring activity, to protect the coupling halves from contamination during periods when the coupling is disengaged. The caps and plugs shall be provided with a suitable chain for attachment to structure.

3.2 Performance Characteristics.

3.2.1 Immersion. The coupling shall meet all performance requirements specified herein after being immersed in hydraulic fluid conforming to MIL-H-83282 at 400°F for a period of 72 hours.

3.2.2 Operating Temperatures. The coupling shall operate satisfactorily during exposure to temperatures from -65 to +400°F.

3.2.3 Pressures.

3.2.3.1 Rated Pressure. The rated operating pressure shall be 8000 psig.

3.2.3.2 Proof Pressure. The coupling shall withstand without permanent deformation a proof pressure of 12,000 psig at +400°F, and shall function satisfactorily when the pressure is reduced to 8000 psig.

3.2.3.3 Burst Pressure. The coupling shall withstand a burst pressure of 17,000 psi at +400° without failure.

3.2.4 Rated Flow. The coupling shall be designed for rated flows as listed on Table II.

TABLE II. Rated Flow nd Maximum Allowable Pressure Drop

Dash No.	Equivalent tube size, O.D., in.	Rated flow, gpm	Pressure drop psi (max)
-3	3/16		
-5	5/16		
-7	7/16		
-9	9/16	TBD	TBD
-11	11/16		
-13	13/16		
-15	15/16		

3.2.5 External Leakage. The connected coupling shall have no external leakage with either low or rated pressure applied. External leakage from the disconnected coupling halves shall not exceed a trace insufficient to form a drop in four (4) hours with low pressure or rated pressure applied.

3.2.6 Pressure Drop. Pressure drop through the connected coupling shall not exceed 25 psi with rated flow at +100°F as specified in Table II.

3.2.7 Vacuum. The coupling shall not leak with 10 inches of mercury vacuum applied.

3.2.8 Surge Flow. There shall be no evidence of flow blockage or internal damage when the coupling is subjected to 100 cycles of surge flow operation.

3.2.9 Vibration. The coupling shall withstand random vibration of 1.0 g^2/Hz over the range of 300 to 1000 Hz.

3.2.10 Impulse. The coupling shall be capable of withstanding 10,000,000 impulse cycles without leakage or failure.

3.2.11 Endurance. The coupling shall withstand 200 coupling and uncoupling operations without malfunction or excessive wear, and with fluid loss plus leakage of not more than the values specified in Table III.

TABLE III. Fluid Loss and Maximum Allowable Air Inclusion

Dash No.	Equivalent tube size, O.D., in.	*Air Inclusion cc (max)	Fluid Loss cc (max)
-3	3/16		
-5	5/16		
-7	7/16		
-9	9/16		
-11	11/16		
-13	13/16		
-15	15/16		

3.2.12 Shock. The coupling shall withstand sawtooth impact shocks up to 20g for durations of not less than 0.011 seconds.

3.2.13 Fluid Loss. The maximum allowable fluid loss occurring in any phase of the coupling or uncoupling operation shall be as specified in Table III. The coupling shall, when uncoupled, seal the ends of the disconnected lines and both low and rated pressures.

3.2.14 Air Inclusion. The volume of air that may be displaced to the inside of the coupling during the coupling operation shall not exceed the values specified in Table III.

3.2.15 Drop Test. The uncoupled ground half shall perform as specified herein, after exposure to 10 impact loads caused by ground personnel dropping the coupling half from a height of 6 feet.

3.3 Dimensions. The couplings shall be the smallest size consistent with good design that is capable of meeting the requirements of this specification.

3.4 Weight. The coupling shall be the lightest weight practical consistent with good design that is capable of meeting the requirements of this specification.

3.5 Color. The attaching half of the coupling shall be color coded for identification purposes. The ends of the coupling shall also be color coded.

3.6 Item Markings. The coupling shall be marked for identification in accordance with MIL-STD-130. In addition, each coupling half shall be permanently marked with the manufacturer's part number and the manufacturer's name or trademark.

3.7 Workmanship. Workmanship shall be of high quality that will insure proper operation and service life of the coupling.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements specified herein. Except as otherwise specified in the contract, the contractor may utilize his own facilities or any other facilities suitable for performance of the inspection requirements specified herein, unless disapproved by the procuring activity. The procuring activity reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of Tests. The inspection requirements specified herein are classified as follows:

a. Performance tests (see 4.4)
b. Quality conformance inspection (see 4.5)
c. Packaging inspection (see 4.6)

4.3 Inspection Conditions. Unless otherwise specified herein, all inspections shall be conducted at a room temperature of $+70^{\circ}$ to $+90^{\circ}F$ and a hydraulic fluid temperature of $+70^{\circ}$ to $+110^{\circ}F$.

4.4 Performance Tests. The qualification inspection shall be as specified in Table IV and shall be conducted in the order listed on one coupling fabricated to nominal dimensions.

TABLE IV. Performance Tests

Inspection	Requirement Paragraph	Test Method Paragraph
Examination of product	3.5 thru 3.9	4.7.1
Fluid immersion	3.2.1	4.7.2
Extreme temperature	3.2.2	4.7.3
Proof pressure	3.2.3.2	4.7.4
External leakage	3.2.5	4.7.5
Pressure drop	3.2.6	4.7.6
Vacuum	3.2.7	4.7.7
Surge flow	3.2.8	4.7.8
Vibration	3.2.9	4.7.9
Impulse	3.2.10	4.7.10
Endurance	3.2.11	4.7.11
Manual operation	3.3	4.7.12
Air inclusion and fluid loss	3.2.13 and 3.2.14	4.7.13
Impact shock	3.2.12	4.7.14
Proof pressure (repeat)	3.2.3.2	4.7.4
Burst pressure	3.2.3.3	4.7.15
Flange strength	3.2.3	4.7.16

4.4.1 Test Report, Test Samples, and Data for the Procuring Activity.. When the tests are conducted at a location other than the laboratory of the procuring activity, the following shall be available for furnishing to that activity:

a. Test report in accordance with MIL-STD-831, and shall include a report of all tests and outline description of test conditions.

b. Test samples that were tested and three untested samples of each size for which qualification is desired, if requested by the qualifying activity within one year subsequent to submittal of Qualified Products List request.

c. Engineering data in the form of detail and assembly drawings. The assembly drawings shall have a cut-away section showing all details in their normal assembly position and shall carry part numbers of all details and subassemblies.

4.5 Quality Conformance Inspection. Each coupling to be furnished under contract shall be subjected to the quality conformance inspections of Table V.

TABLE V. Quality Conformance Inspection

Inspection	Requirement Paragraph	Test Method Paragraph
Examination of product	3.1, 3.3 thru 3.7	4.7.1
Proof pressure	3.2.3.2	4.7.4
Leakage at low pressure	3.2.5	4.7.5.1

4.6 Packaging Inspection. The inspection of the preservation-packaging and interior package marking shall be in accordance with the applicable group quality conformance inspection requirements of MIL-P-116. The inspection of the packing and marking for shipment and storage shall be in accordance with the quality assurance provisions of the applicable packing specification for the proper level and the marking requirements of MIL-STD-129.

4.7 Methods of Examination and Test.

4.7.1 Examination of Product. Each coupling shall be carefully examined to determine conformance to the requirements of this specification for design, weight, workmanship, marking, conformance to applicable government and manufacturer's drawings, specifications and standards, and for any visible defects.

4.7.2 Fluid Immersion. The coupling shall be immersed continuously in hydraulic fluid conforming to MIL-H-83282 for a period of 72 hours at a temperature of 400 ± 5°F. All internal parts of the coupling shall be in contact with the fluid. After this 72-hour soak period, the coupling shall be subjected to the extreme temperature testing of 4.7.3 immediately or remain in the fluid at room temperature until ready for test. The coupling shall not be exposed to air internally for any appreciable time during qualification testing.

4.7.3 Extreme Temperature.

4.7.3.1 High Temperature. A 30-inch static head of hydraulic fluid shall be applied to the connected coupling at a temperature of 400 ± 5°F for a period of 6 hours. There shall be no measurable leakage from the coupling during the 6-hour period. The coupling shall then be cooled to +140 ± 5°F and five cycles of coupling and uncoupling shall be completed. There shall be no binding during any cycle of disconnection and connection. The temperature of the uncoupled halves shall be raised to +225 ± 5°F and each half subjected to the leakage tests of 4.7.5.1 and 4.7.5.2.

4.7.3.2 Low Temperature. A 30-inch static head of hydraulic fluid shall be applied to the connected coupling at a temperature not warmer than -65°F for a period of 4 hours. There shall be no measurable leakage from the coupling during this period. Five cycles of coupling and uncoupling shall then be completed. There shall be no binding during any cycle of disconnection and connection. The uncoupled halves shall each be subjected to the leakage tests of 4.7.5.1 and 4.7.5.2. The coupling temperature will be allowed to rise to -30°F during the coupling/uncoupling leakage tests.

4.7.3.3 Rapid Warmup. The connected coupling shall be warmed rapidly from -65°F to +65°F with a 30-inch static head of hydraulic fluid applied. The coupling shall be disconnected and connected at approximately 20°F increments during the warm-up period without waiting for temperature stabilization. There shall be no binding or other malfunction.

4.7.4 Proof Pressure. This test shall be conducted at 400 ± 5°F for the qualification test, and at room temperature for the quality conformance test. The connected coupling and the uncoupled halves shall be subjected to a proof pressure of 12,000 ± 500/-0 psig for a period of 30 seconds. There shall be no leakage greater than that specified in 4.7.5.3 or any permanent deformation or other malfunction of the coupling. The coupling shall function normally after having been subjected to this test. For quality conformance inspection conduct at 100°F.

4.7.5 External Leakage.

4.7.5.1 Leakage at Low Pressure (Qualification Inspection. A 30-inch static head of hydraulic fluid shall be applied to the connected coupling and to the disconnected halves for a period of 4 hours. All external surfaces shall be dry at the beginning of this test. There shall be no external leakage from the connected coupling. Leakage from the disconnected halves shall not exceed a trace insufficient to form a drop at the end of the 4-hour test period.

4.7.5.2 Leakage at Low Pressure (Quality Conformance Inspection. A 30-inch static head of hydraulic fluid shall be applied to the connected coupling and to the disconnected halves for a period of one (1) minute. All external surfaces shall be dry at the beginning of this test. There shall be no external leakage from either the connected coupling or the disconnected halves.

4.7.5.3 Leakage at High Pressure. Both the connected coupling and the disconnected halves shall be subjected to a static pressure of 8000 psig for a period of 15 minutes. All external surfaces shall be dry at the beginning of this test. There shall be no external leakage from the connected coupling. Leakage from the disconnected halves shall not exceed a trace insufficient to form a drop.

4.7.6 Pressure Drop. Pressure drop through the connected coupling shall be determined for rated flow using a setup similar to that depicted on Figure 1. Return pressure shall be 100 psig and the fluid temperature shall be $+100^{0} \pm 5^{0}$F. The pressure drop in each direction through the coupling shall not exceed 25 psig. The pressure drop in the coupling shall be considered to be the difference between (1) the drop through the coupling and connecting tubing and (2) the drop through a single straight tube used to replace the coupling and connecting tubing.

4.7.7 Vacuum. A vacuum equivalent to 10 inches of mercury shall be applied to the connected coupling. The vacuum shall be trapped in the coupling for 5 minutes during which time there shall be no change in pressure.

4.7.8 Surge Flow. The coupling shall be subjected to a flow equal to 5 times rated flow for 5 seconds duration in each direction, alternately. The operating pressure level shall be less than 500 psig. The surge flow pattern shall be repeated 100 times. There shall be no evidence of flow blockage or internal damage as a result of this test. Leakage from the disconnected halves shall not exceed the values specified in 4.7.5 after completion of the surge flow test.

4.7.9 Vibration.

4.7.9.1 Resonance. The connected coupling shall be filled with fluid and tested for resonance along 2 axes; perpendicular to and parallel to the coupling axis. An accelerometer shall be mounted on the coupling. The frequency, amplitude, and acceleration levels shall be slowly varied to within +0, -10 percent of that specified for vibration tests in Procedure XII, Figure 1, of MIL-E-5272. All resonant frequencies and their magnitude shall be noted.

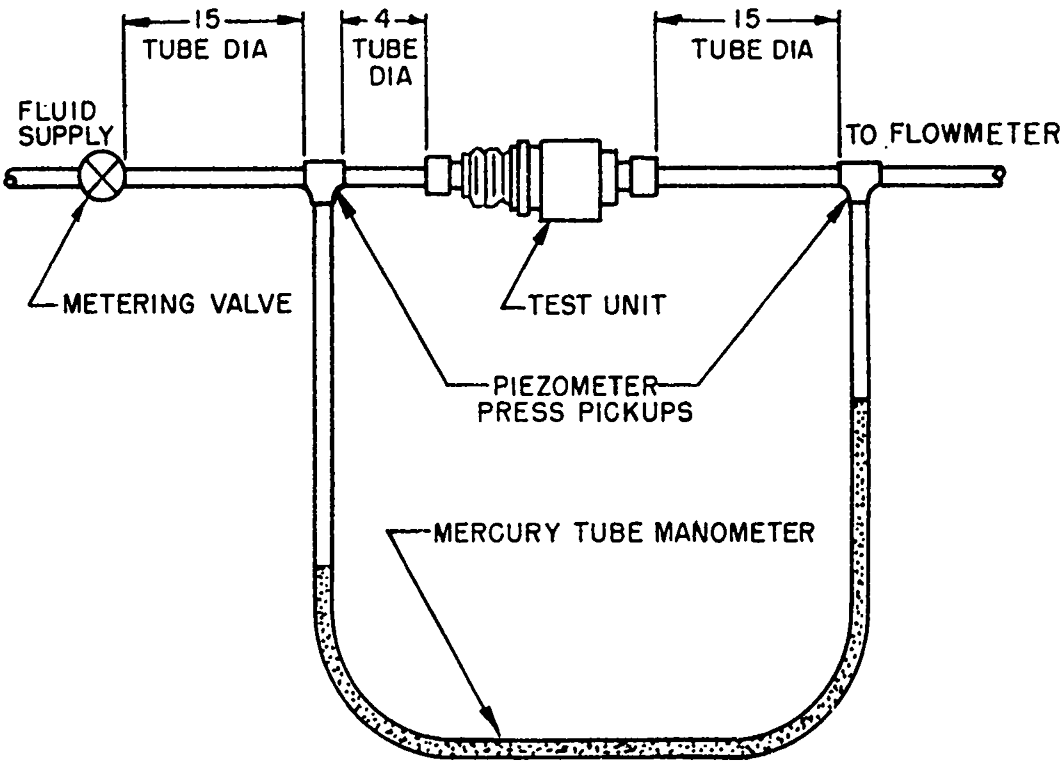


FIGURE 1. Setup for Pressure Drop Test.

4.7.9.2 Fatigue. The connected coupling shall be tested in a setup similar to that shown in Figure 2. The coupling shall be vibrated for 25 hours along an axis perpendicular to the coupling axis, then 25 hours along an axis parallel to the coupling axis. The vibration frequency used shall be the most severe resonance frequency observed for each axis in 4.7.9.1. If a major resonant frequency does not exist along either axis, the coupling shall be vibrated at 55 Hertz with a double amplitude of 0.060 inch. The first 25 percent of each 25-hour test shall be conducted at 400 $\pm$ 5°F. The remaining 75 percent shall be conducted at +225° $\pm$ 10°F.

4.7.10 Impulse. Impulse pressure conforming to the curve shown in Figure 3(a) or 3(b) shall be applied to the inlet manifold at a rate not below the minimum specified. Electronic measuring equipment shall be used to monitor the wave form. The test fluid shall be MIL-H-83282.

The coupling shall withstand 10,000,000 impulse cycles without evidence of failure, and leakage shall not exceed the values specified in 4.7.5 after completion of the fatigue test.

4.7.11 Endurance. A pressure of 15 psig shall be applied to each half of the disconnected coupling. The coupling shall then be subjected to 200 connecting and disconnecting operations. The coupling shall withstand this test without malfunction or excessive wear. After completion of the test, the fluid loss plus leakage shall be checked and shall not exceed the applicable value specified in Table III.

4.7.12 Manual Operation. The mounting half of the coupling shall be secured in a fixed position, and a static pressure of 100 psig shall be applied to both halves. One hand shall be used to connect and disconnect the coupling without tools. This test shall be repeated 500 times. Connection/disconnection shall be accomplished with relative ease and without malfunction. The fluid loss plus leakage shall not exceed the applicable value of Table III.

Coupling operation shall be checked to determine that no partially coupled, unlocked position exists that is stable and would permit fluid flow.

4.7.13 Air Inclusion and Fluid Loss. Air inclusion and fluid loss shall be determined using a setup similar to that depicted on Figure 4. Air inclusion that occurs during ten (10) consecutive uncoupling/coupling operations shall not total more than ten (10) times the maximum allowable values specified in Table III. Fluid loss that occurs during ten (10) consecutive uncoupling/coupling operations shall not total more than ten (10) times the maximum allowable values specified in Table III.

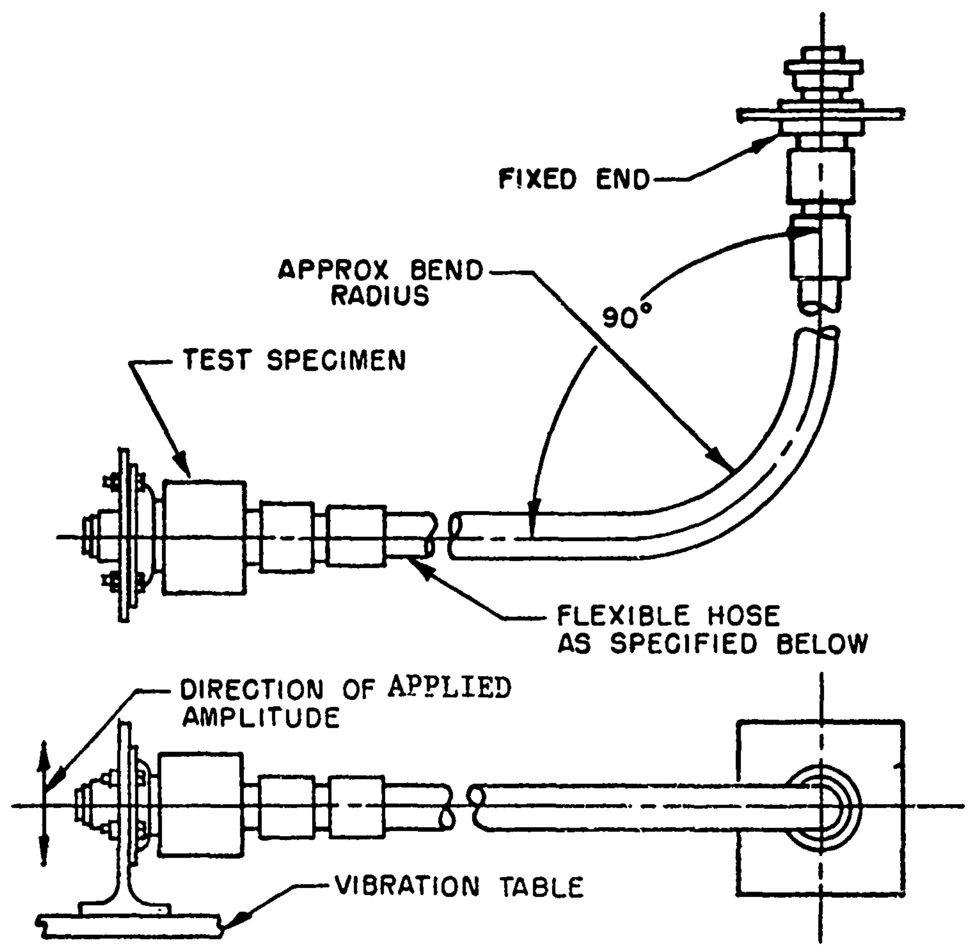


Figure 2. Vibration Test Setup

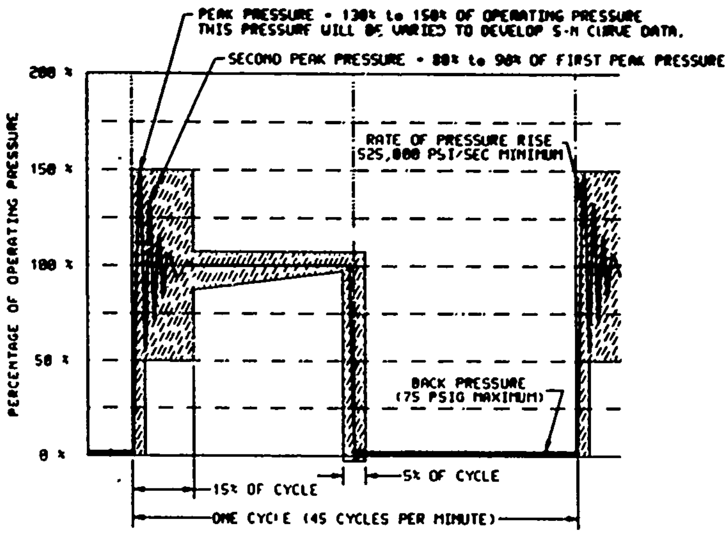


Figure 3(a) Damped Wave

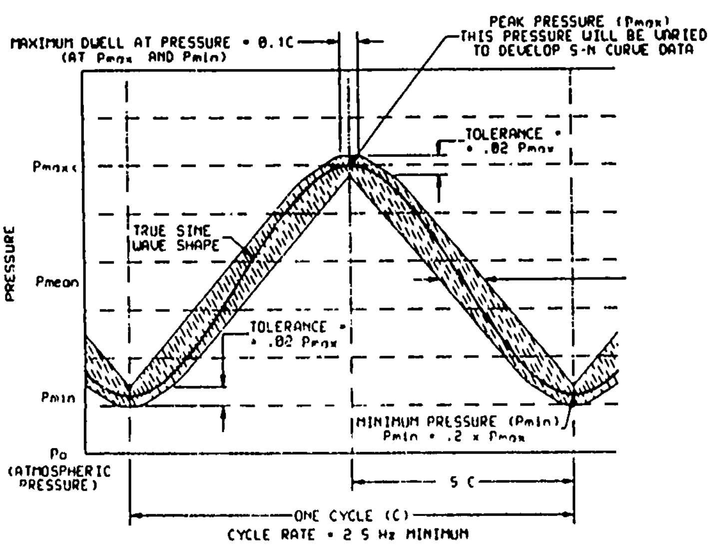
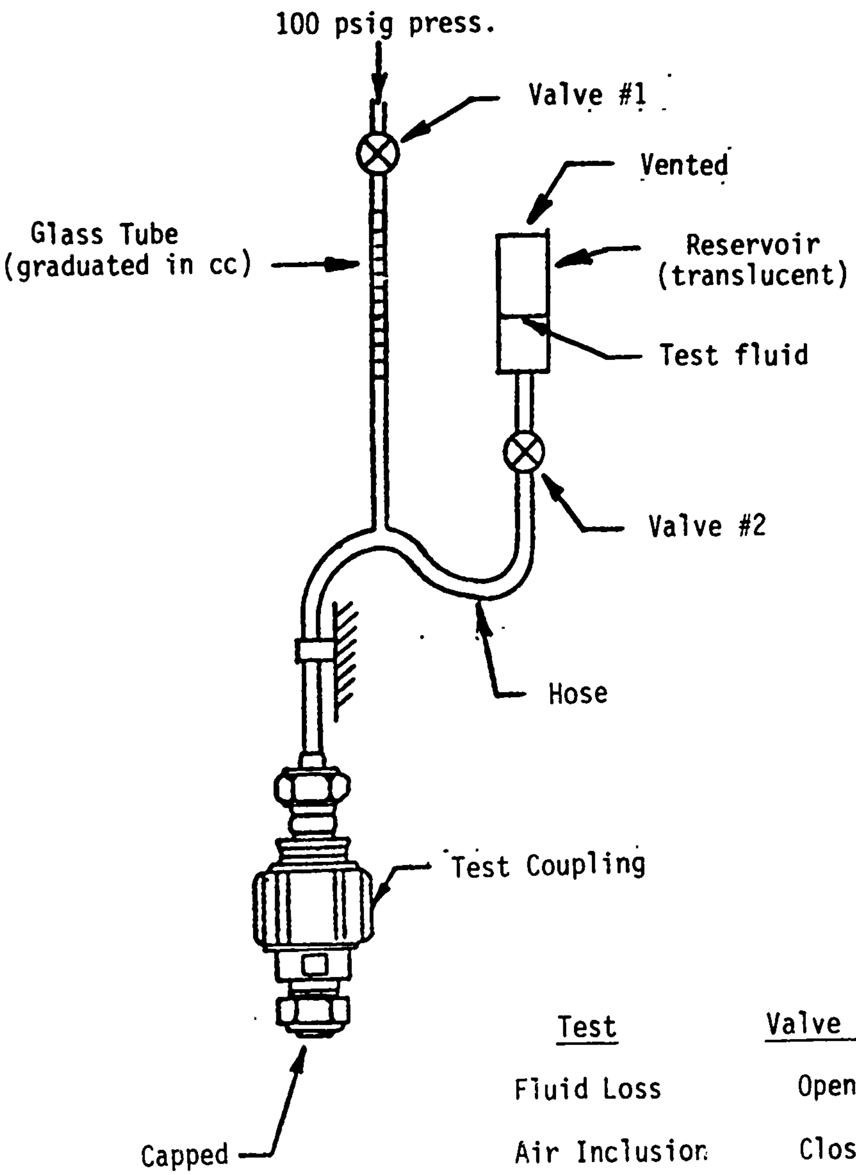


Figure 3(b) Sine Wave

FIGURE 3. <u>Graph of Pressure Impulse Cycle.</u>



Test	Valve #1	Valve #2
Fluid Loss	Open	Closed
Air Inclusion	Closed	Open

FIGURE 4. Air Inclusion and Fluid Loss Test Setup

4.7.14 Impact Shock. The connected coupling shall be subjected to 12 impact shocks of 20g ± 10%. The shock peak shall be reached in approximately 5 milliseconds and the impulse shall have a duration of 10 ± 1 milliseconds. The coupling shall be filled with fluid and a static pressure of 15 psig shall be applied during the shock test. The shocks shall be applied as follows:

a. Parallel to coupling axis, three shocks in each direction.
b. Perpendicular to coupling axis, three shocks in each direction.

Inadvertent uncoupling shall not occur as a result of this test.

4.7.15 Burst Pressure. This test shall be performed at a temperature of $400^{\circ} \pm 5^{\circ}F$ on the connected coupling and the disconnected halves. Pressure shall be applied at a rate of approximately 25,000 psig per minute until a pressure of 17,000 +100, -0 psig is obtained. The coupling shall withstand the burst pressure for a period of 2 minutes without rupture or other failure and external leakage shall not exceed 1 drop per minute.

4.7.16 Flange Strength. The mounting half of the coupling shall be mounted by means of its flange to a bulkhead. A fitting nut shall be threaded on the coupling. A torque equal to 1.5 times the maximum wrenching torque as specified in Table III shall be applied to the fitting nut 15 times. No failure or permanent deformation shall occur in the flange as a result of this test.

5. PACKAGING

The preservation-packaging and interior package marking shall be in accordance with the applicable group quality conformance inspection requirements of MIL-P-116. The inspection of the packing and marking for shipment and storage shall be in accordance with the quality assurance provisions of the applicable packing specification for the proper level and the marking requirements of MIL-STD-129. All openings shall be sealed with metal caps or plugs conforming to MIL-C-5501.

6. NOTES AND CONCLUDING MATERIAL

6.1 Intended Use. The couplings covered by this specification are intended for use in aircraft 8000 psi hydraulic systems and may be used in ground servicing installations, near pump installations, or other installations requiring frequent uncoupling of hydraulic lines rated for 8000 psi service.

6.2 Ordering Data. The contract should specify the following:

a. Title, number, and date of this specification.
b. Type and size required (see 1.2 and 1.3).
c. Group of preservation-packaging (see 1.5).
d. Level of packing (see 5.0).

APPENDIX B

SCREENING TEST:
COMPARISON OF SUPPLIER HARDWARE PERFORMANCE

3/16-INCH FITTINGS - PRESSURE IMPULSE FATIGUE SUMMARY

SUPPLIER	SPECIMEN I.D.	S/N	PEAK PRESS (PSI)	CYCLES TO FAILURE	NOTES
RAYCHEM	A-RC-03-021	1	20,000	18,941	Tube Crack
		2	16,000	47,443	Tube Crack
		3	14,000	28,236	Tube Crack
		4	12,000	1,987,777	(Running)
		5			
		6			
DEUTSCH	A-DC-03-021	1A	20,000	13,956	Tube Crack
		1	16,000	35,775	
		2	14,000	67,270	Tube Crack
		3	14,000	4,580	Twisted on Installation
		4	12,000	215,231	Leak at T/F Interface
		5			
		6			
AEROFIT PRODUCTS	B-AF 03-021	1	20,000	29,051	Tube Crack
		2	16,000	106,648	Tube Crack
		3	14,000	157,589	B-Nut Seal Leak
		4	12,000	1,798,342	(Running)
		5			
		6			
AIRDROME	B-AD-03-021	1	20,000	13,985	Tube Crack
		2	16,000	36,618	Tube Crack
		3	14,000	61,590	Tube Crack
		4	12,000	80,833	Tube Crack - 1/4" from Weld
		5			
		6			
AEROQUIP LINAIR	B-TL-03-021	1	16,000	671,485	No Failure (NAVY)
		2	20,000	538,821	Collet Crack (NAVY)
		7	20,000	17,569	Tube Crack (RI Tube)
		8	14,000	2,642,940	(Running)
		9			
		10	14,000	1,688,711	(Running)
		11	12,000	1,562,644	(Running)
		12			
RESISTOFLEX	B-RX-03-021	1	20,000	17,364	Tube Crack
		2	16,000	24,792	Tube Rupture
		3	14,000	61,748	Tube Crack
		4	12,000	1,643,477	(Running)
		5			
		6			

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15/16-INCH FITTINGS - PRESSURE IMPULSE FATIGUE SUMMARY

SUPPLIER	SPECIMEN I.D.	S/N	PEAK PRESS (PSI)	CYCLES TO FAILURE	NOTES
RAYCHEM	A-RC-15-105	1	20,000	41,815	Crack in Tube
		2	16,000	455,705	Crack in Coupling
		3	14,000	509,504	Crack in Coupling
		4	12,000	681,049	Crack in Coupling
		5			
		6			
DEUTSCH	A-DE-15-105	1	20,000	6,709	Leak in Slug
		2	20,000	18,733	T/F Interface Leak
		3	16,000	56,632	T/F Interface Leak
		4	14,000	374,156	Crack in Slug
		5	12,000	1,987,777	(Running)
		6			
AEROFIT PRODUCTS	B-AF-15-105	1	20,000	393	Leak at B-Nut Seal
	B-AF-15-105 (mod-1)	2	16,000	48,288	Tube Weld Leak
		3	20,000	1,510	Fretting at Seal
		4	14,000	45,583	Pinhole, in Weld
		5	12,000	189,435	Crack in Weld
		6			
AIRDROME	B-AD-15-105	1	16,000	4,462	Crack, Lip Seal Head
		2			
		3			
RESISTOFLEX	B-RX-15-105	1	18,200	0	Ftg Blew @ Proof Pres
		2	16,500	129	Ftg Blew @ Swage
		3	16,000	3,738	Ftg Rupture
		4	20,000	6,224	Crack, Lip Seal Head
		5	14,000	21,591	Crack, Swage Collar
		6	12,000	80,223	Crack, Swage Collar
AEROQUIP LINAIR	B-TL-15-105	1	20,000	1,284	Leak at Lip Seal
		2	20,000	4,516	Leak at Lip Seal
		3	20,000	3,500	Leak at Lip Seal
		8	16,000	2,235	Leak at B-Nut
	B-TL-15-105	9	14,000	202,634	Leak at FTG, Swage
		10	12,000	247,910	Leak at FTG, Swage
		11			
		12			
	B-TL-15-105 (mod-1)	4	20,000	1,571	Leak at B-Nut
		5	16,000	1,940	Leak at B-Nut
	B-TL-15-105 (SPL)	1	20,000	1,571	Leak at B-Nut
		13	14,000	41,738	Leak, B-Nut, Face Seal Crack

FILE: PIFS2

9 NOV 1988

3/16-INCH QUICK DISCONNECTS - PRESSURE IMPULSE FATIGUE SUMMARY

SUPPLIER	SPECIMEN I.D.	S/N	PEAK PRESS (PSI)	CYCLES TO FAILURE	NOTES
SYMETRICS	F-SY-03	1	16,000	79,367	Nipple Crack
		2	14,000	385,487	Leak thru Nipple
		3			
		4			
		5			
		6			
SEATON - WILSON	F-SW-03	1	16,000	13,473	Coupling Rupture
		2			
		3			
		4			
		5			
		6			
	F-SW-03 (mod-1)	7	14,000	64,176	Leak thru Nipple
AEROQUIP	F-AQ-03	1			
		2			
		3	14,000	1,083,836	(Running)
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			

FILE: PIFS5 9 NOV 1988

15/16-INCH QUICK DISCONNECTS - PRESSURE IMPULSE FATIGUE SUMMARY

SUPPLIER	SPECIMEN I.D.	S/N	PEAK PRESS (PSI)	CYCLES TO FAILURE	NOTES
SYMETRICS	F-SY-15	1			
		2			
		3			
		4			
		5			
		6			
SEATON - WILSON	F-SW-15	1			
		2			
		3			
		4			
		5			
		6			
AEROQUIP	F-AQ-15	1	14,000	47,214	No Failure
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			

FILE: PIFS6 9 NOV 1988

3/16-INCH SWIVELS - PRESSURE IMPULSE FATIGUE SUMMARY

SUPPLIER	SPECIMEN I.D.	S/N	PEAK PRESS (PSI)	CYCLES TO FAILURE	NOTES
F. KRUEGER	E-RK-03	1	16,000	170,235	Pin Hole Leak in Body
		2	14,000	24,889	Seal Leak
		3			
		4			
		5			
		6			
DEUTSCH	E-DE-03	1	14,000	236,149	Crack in Boss on Body
		2			
		3			
		4			
		5			
		6			
AEROQUIP	E-AQ-03	1	20,000	207,581	Leak at Rotary Seal
		2	14,000	49,565	Leak at Rotary Seal
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			

FILE: PIFS3 9 NOV 1988

15/16-INCH SWIVELS - PRESSURE IMPULSE FATIGUE SUMMARY

SUPPLIER	SPECIMEN I.D.	S/N	PEAK PRESS (PSI)	CYCLES TO FAILURE	NOTES
F. KRUEGER	E-RK-15	1	14,000	143,668	Leak/Rotary Seal-6 Seal Chngs
		2			
		3			
		4			
		5			
		6			
DEUTSCH	E-DE-15	1	14,000	142	Leak at Rotary Seal
		2			
		3			
		4			
		5			
		6			
AEROQUIP	E-AQ-15	1	14,000	100,254	No Failure
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			

FILE: PIFS4

9 NOV 1988

15/16-INCH HOSES - PRESSURE IMPULSE FATIGUE SUMMARY

SUPPLIER	SPECIMEN I.D.	S/N	PEAK PRESS (PSI)	CYCLES TO FAILURE	NOTES
AEROQUIP	C-AQ-15	1	14,000	2,957	Leak - Hose/Swage
		2			
		3			
		4			
		5			
		6			
TITEFLEX	C-TX-15	1	14,000	64,176	Hose and Overbraid Rupture
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			
		1			
		2			
		3			
		4			
		5			
		6			

FILE: PIFS8 9 NOV 1988

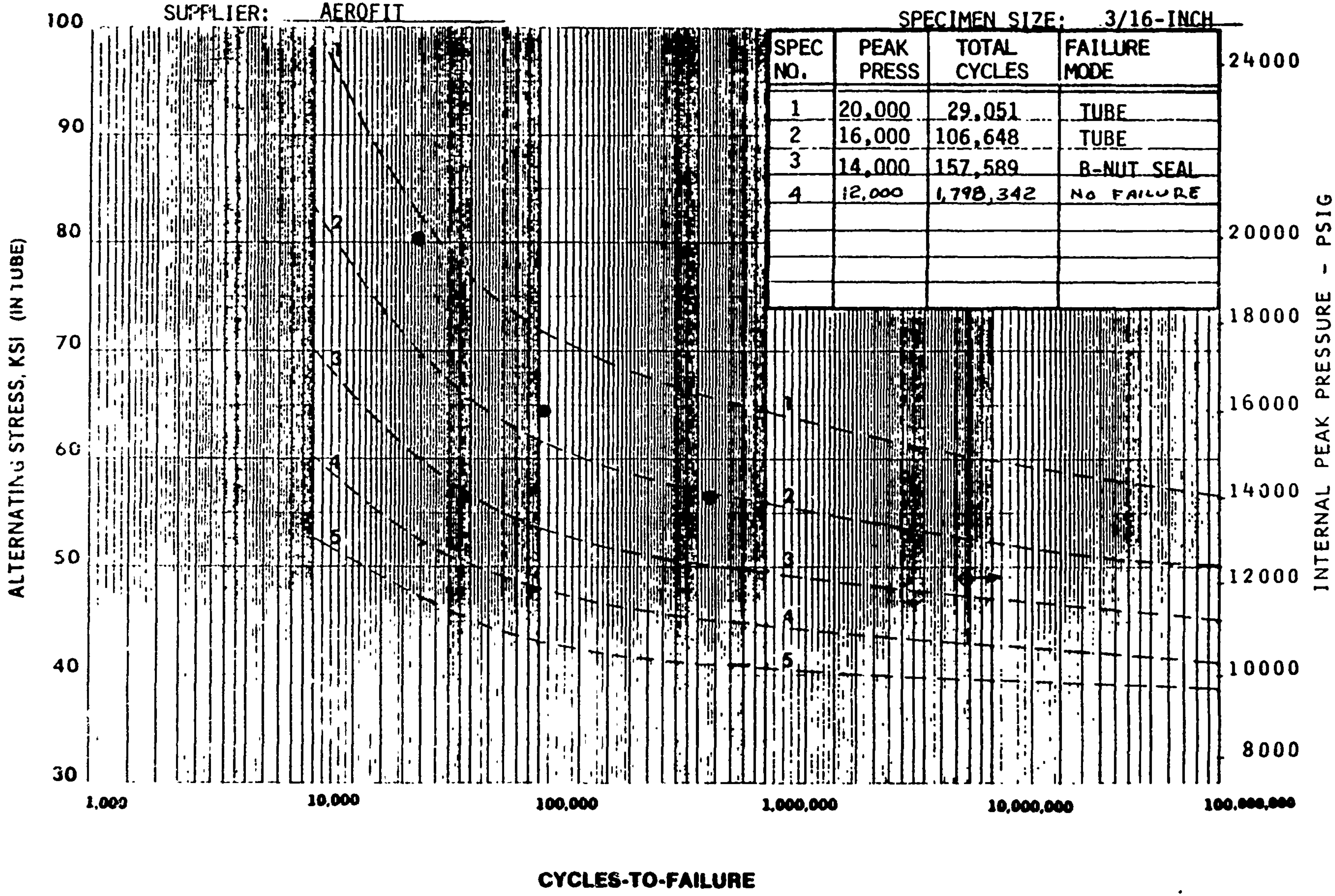
DETACHABLE FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: AEROFIT

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	20,000	29,051	TUBE
2	16,000	106,648	TUBE
3	14,000	157,589	B-NUT SEAL
4	12,000	1,798,342	NO FAILURE



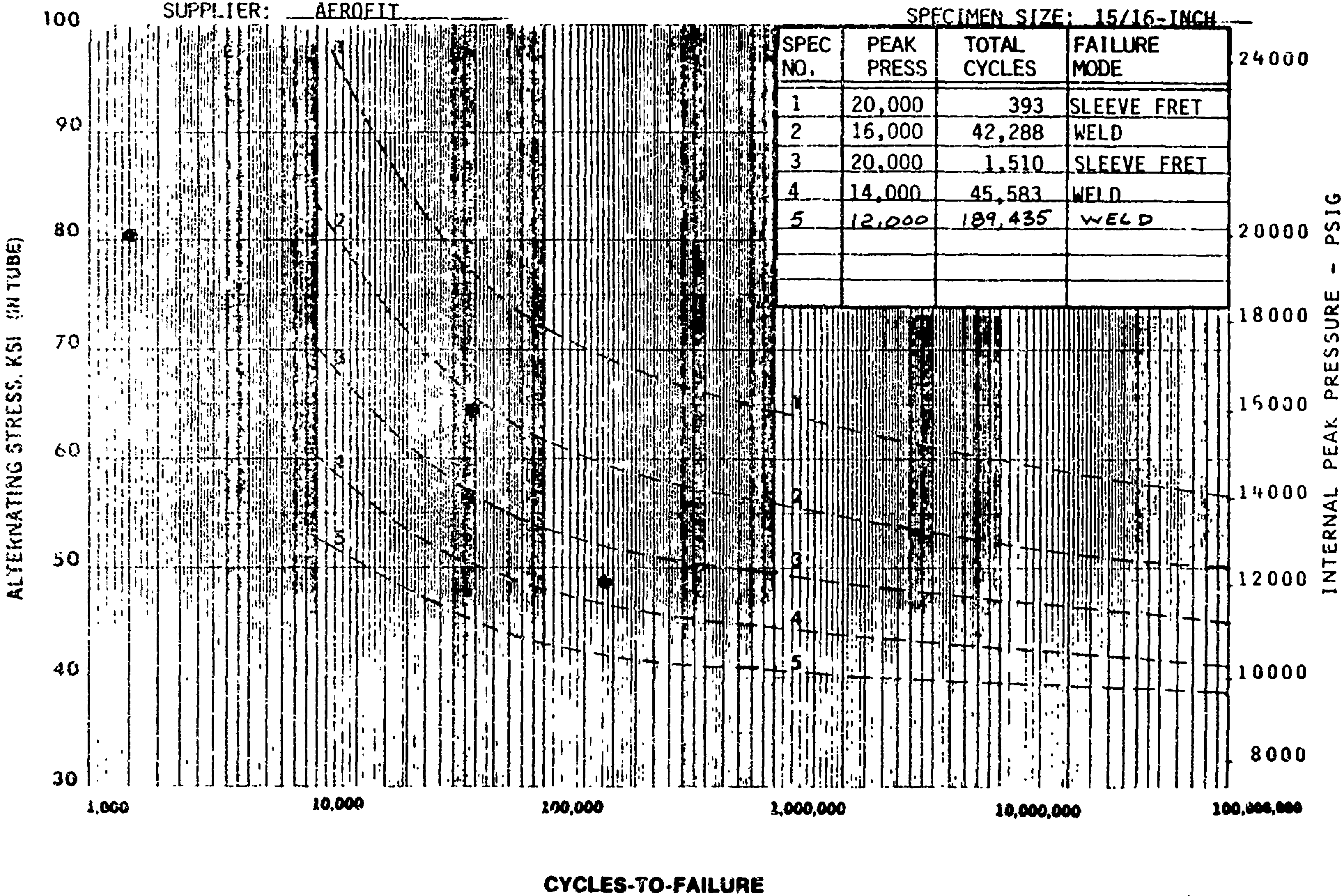
DETACHABLE FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: AEROFIT

SPECIMEN SIZE: 15/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	20,000	393	SLEEVE FRET
2	16,000	42,288	WELD
3	20,000	1,510	SLEEVE FRET
4	14,000	45,583	WELD
5	12,000	189,435	WELD



DETACHABLE FITTINGS

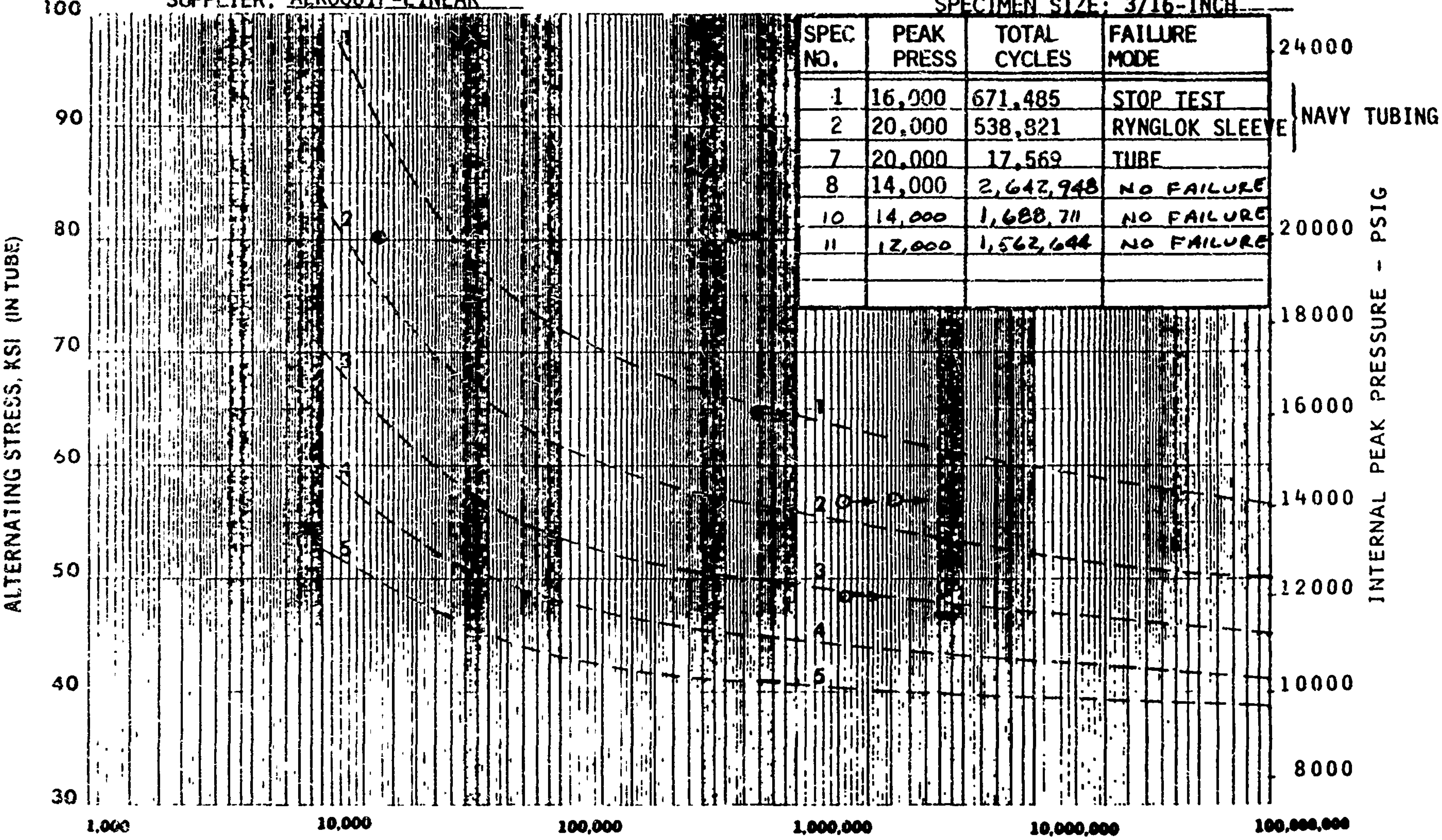
PRESSURE IMPULSE RESULTS

SUPPLIER: AEROQUIP-LINEAR

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	16,000	671,485	STOP TEST
2	20,000	538,821	RYNGLOK SLEEVE
7	20,000	17,569	TUBE
8	14,000	2,642,948	NO FAILURE
10	14,000	1,688,711	NO FAILURE
11	12,000	1,562,644	NO FAILURE

NAVY TUBING (specimens 1 and 2)



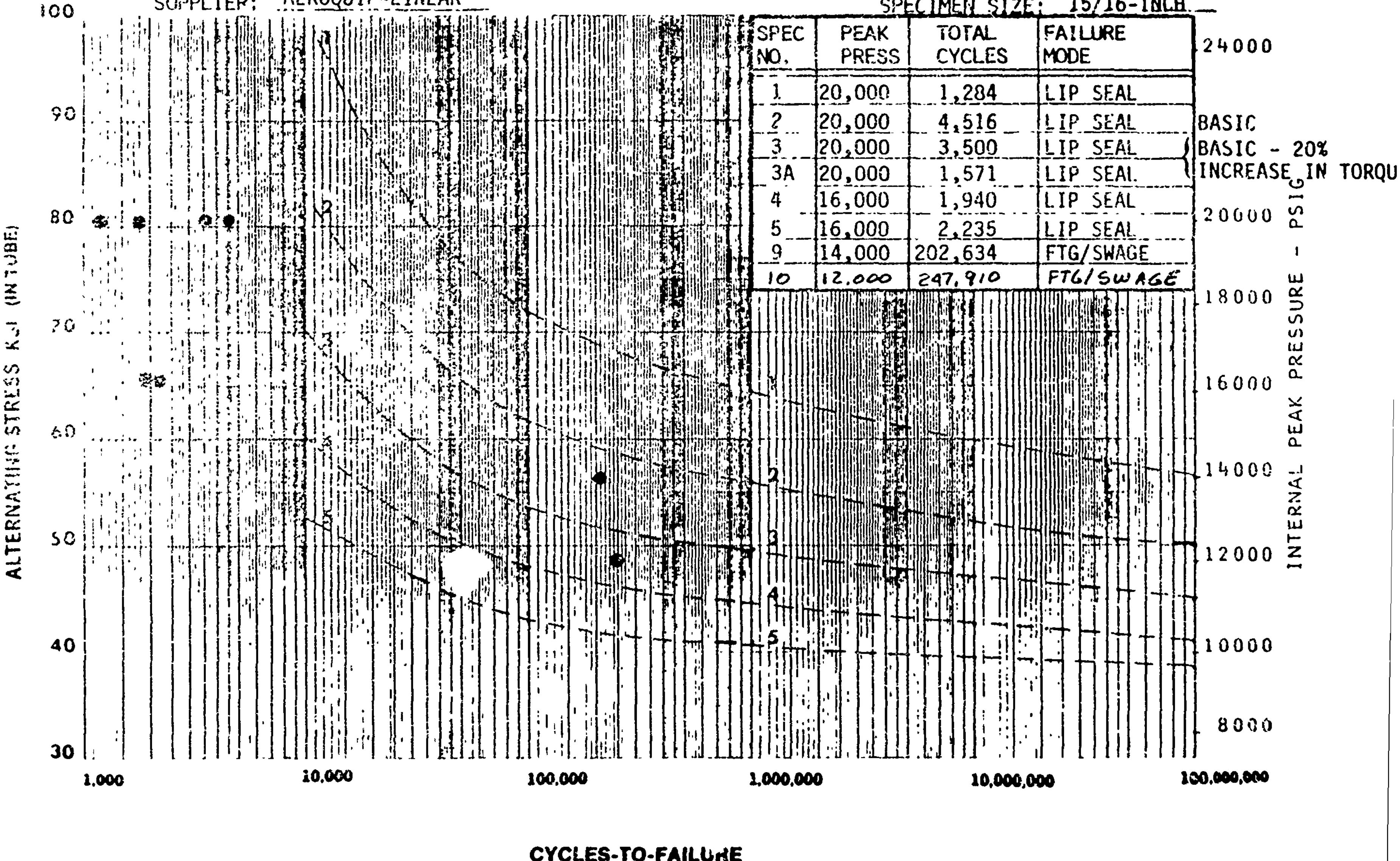
TEST STOPPED - NO FAILURE

DETACHABLE FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: AEROQUIP-LINEAR

SPECIMEN SIZE: 15/16-INCH



SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE	
1	20,000	1,284	LIP SEAL	
2	20,000	4,516	LIP SEAL	BASIC
3	20,000	3,500	LIP SEAL	BASIC - 20% INCREASE IN TORQU
3A	20,000	1,571	LIP SEAL	
4	16,000	1,940	LIP SEAL	
5	16,000	2,235	LIP SEAL	
9	14,000	202,634	FTG/SWAGE	
10	12,000	247,910	FTG/SWAGE	

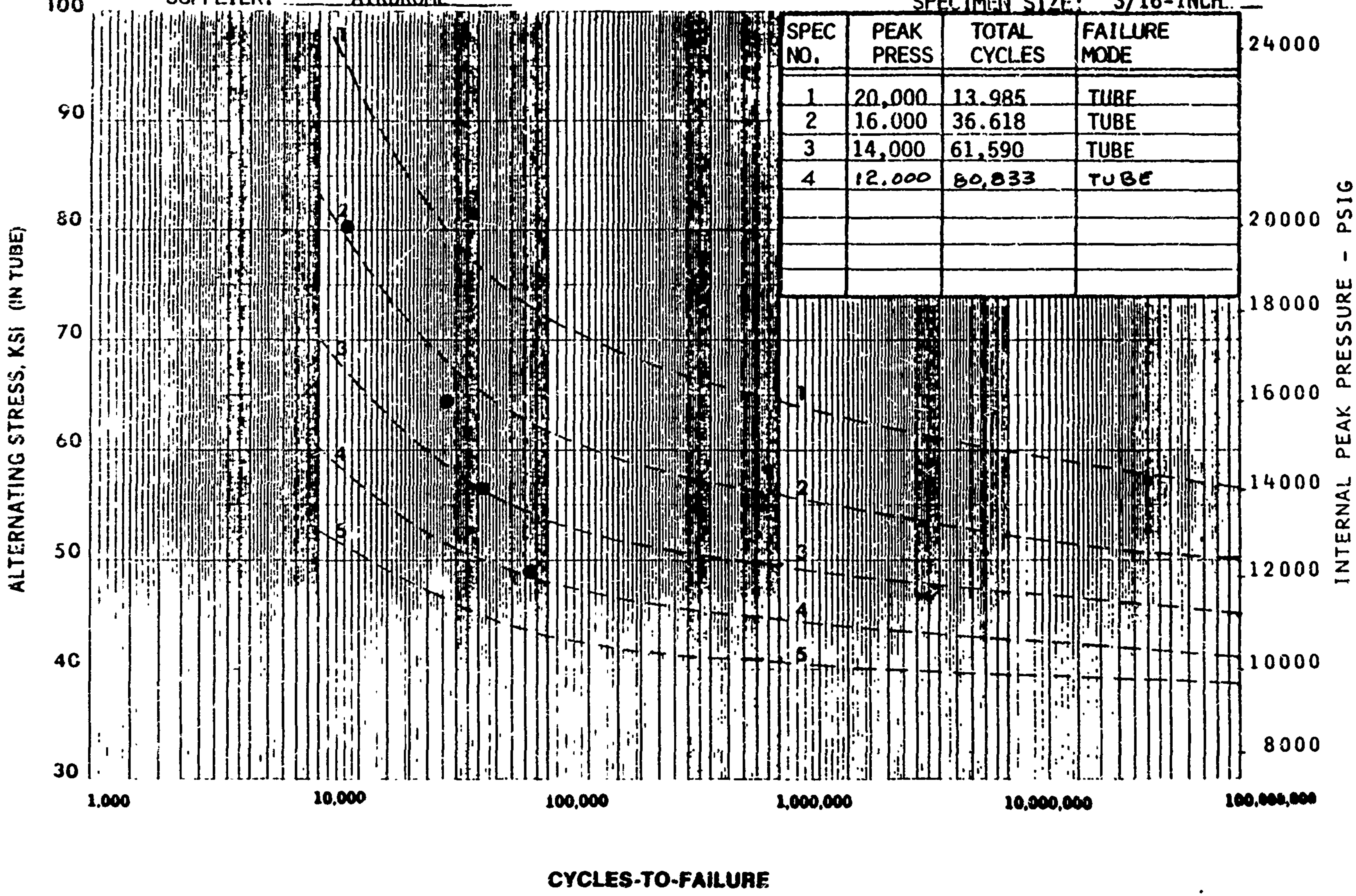
DETACHABLE FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: AIRDROME

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	20,000	13,985	TUBE
2	16,000	36,618	TUBE
3	14,000	61,590	TUBE
4	12,000	80,833	TUBE



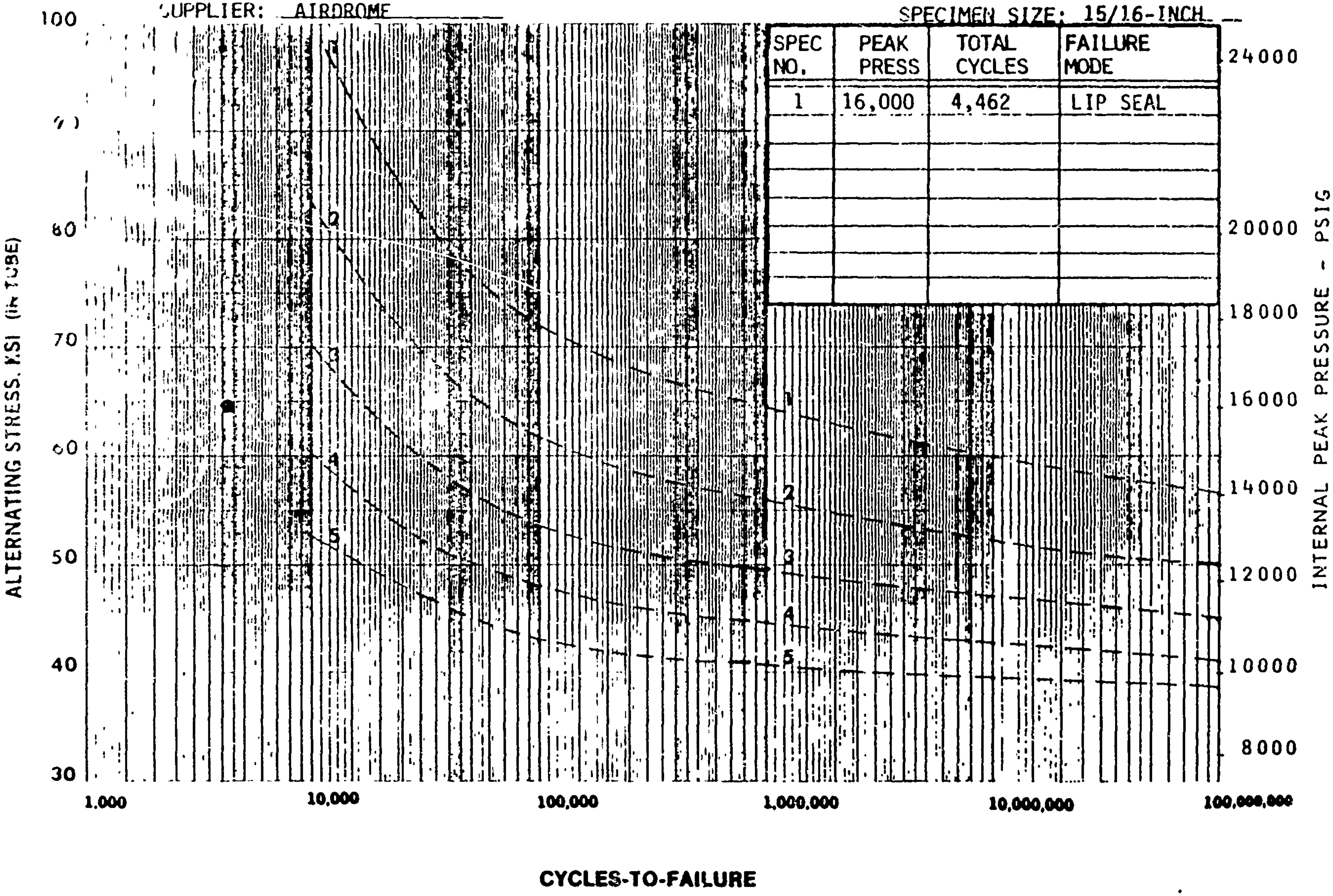
DETACHABLE FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: AIRDROME

SPECIMEN SIZE: 15/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	16,000	4,462	LIP SEAL

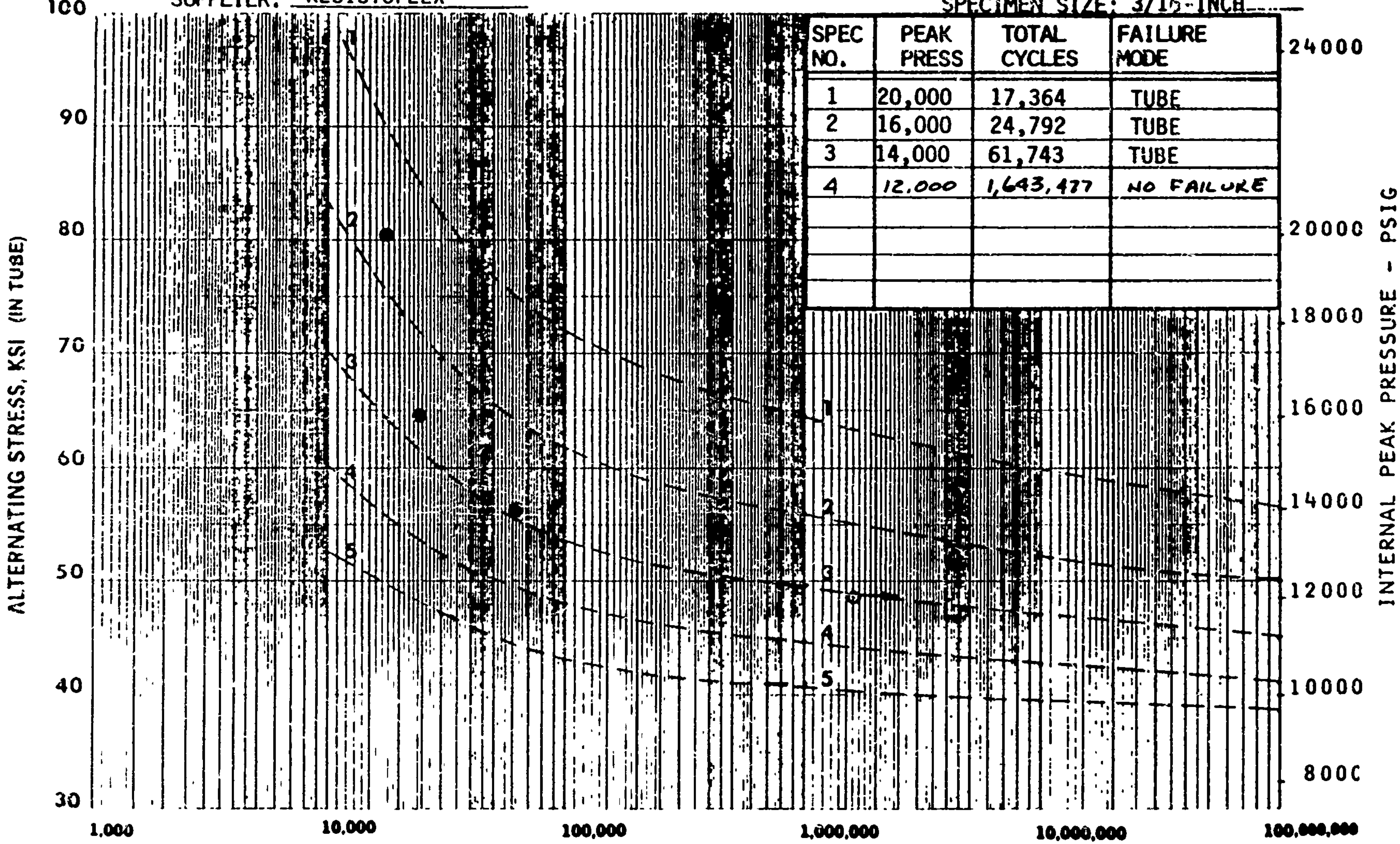


DETACHABLE FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: RESISTOFLEX

SPECIMEN SIZE: 3/16-INCH



SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	20,000	17,364	TUBE
2	16,000	24,792	TUBE
3	14,000	61,743	TUBE
4	12,000	1,643,477	NO FAILURE

PERMANENT FITTINGS DETACHABLE FITTINGS

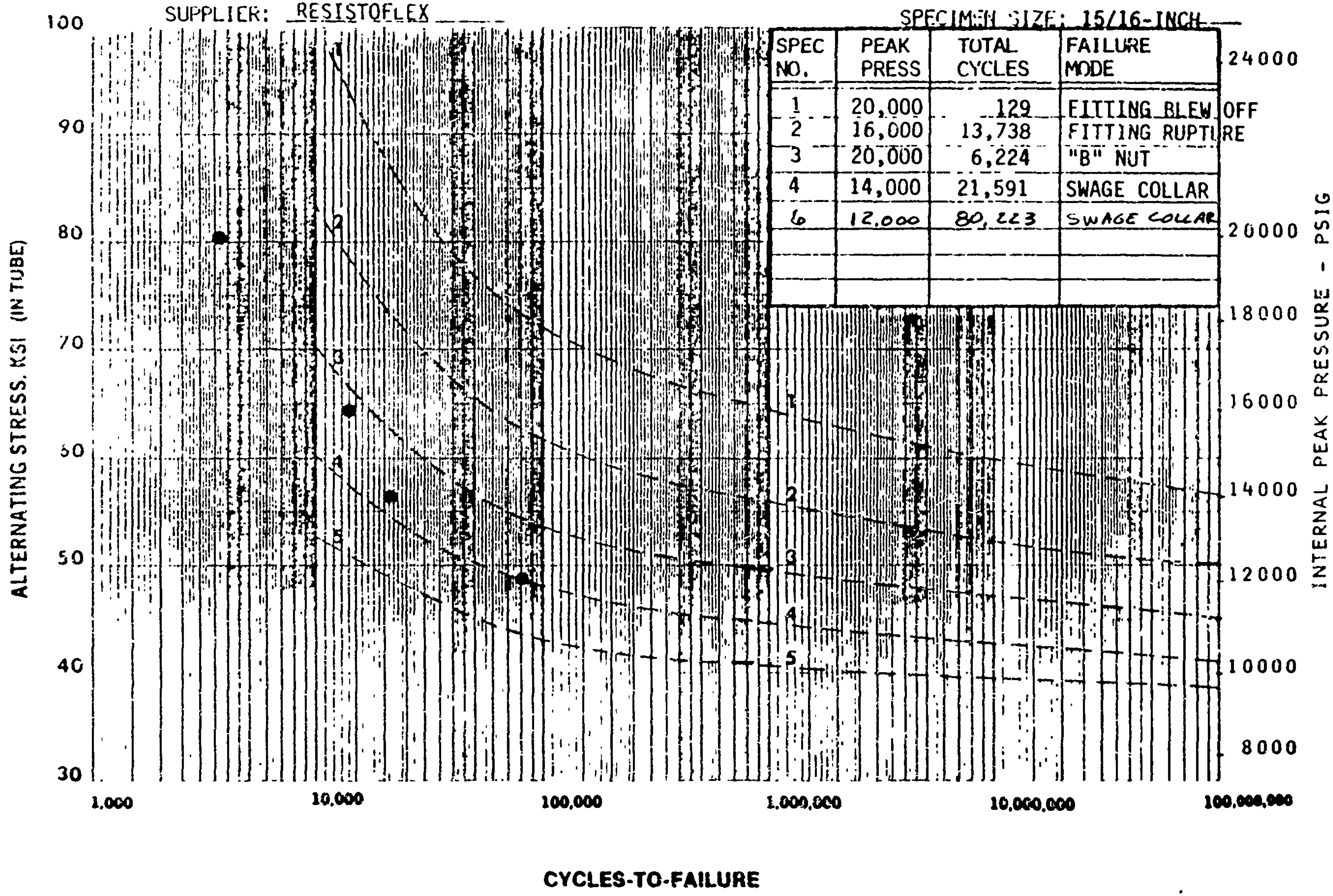
DETAC ABLE

PRESSURE IMPULSE RESULTS

SUPPLIER: RESISTOFLEX

SPECIMEN SIZE: 15/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	20,000	129	FITTING BLEW OFF
2	16,000	13,738	FITTING RUPTURE
3	20,000	6,224	"B" NUT
4	14,000	21,591	SWAGE COLLAR
6	12,000	80,223	SWAGE COLLAR



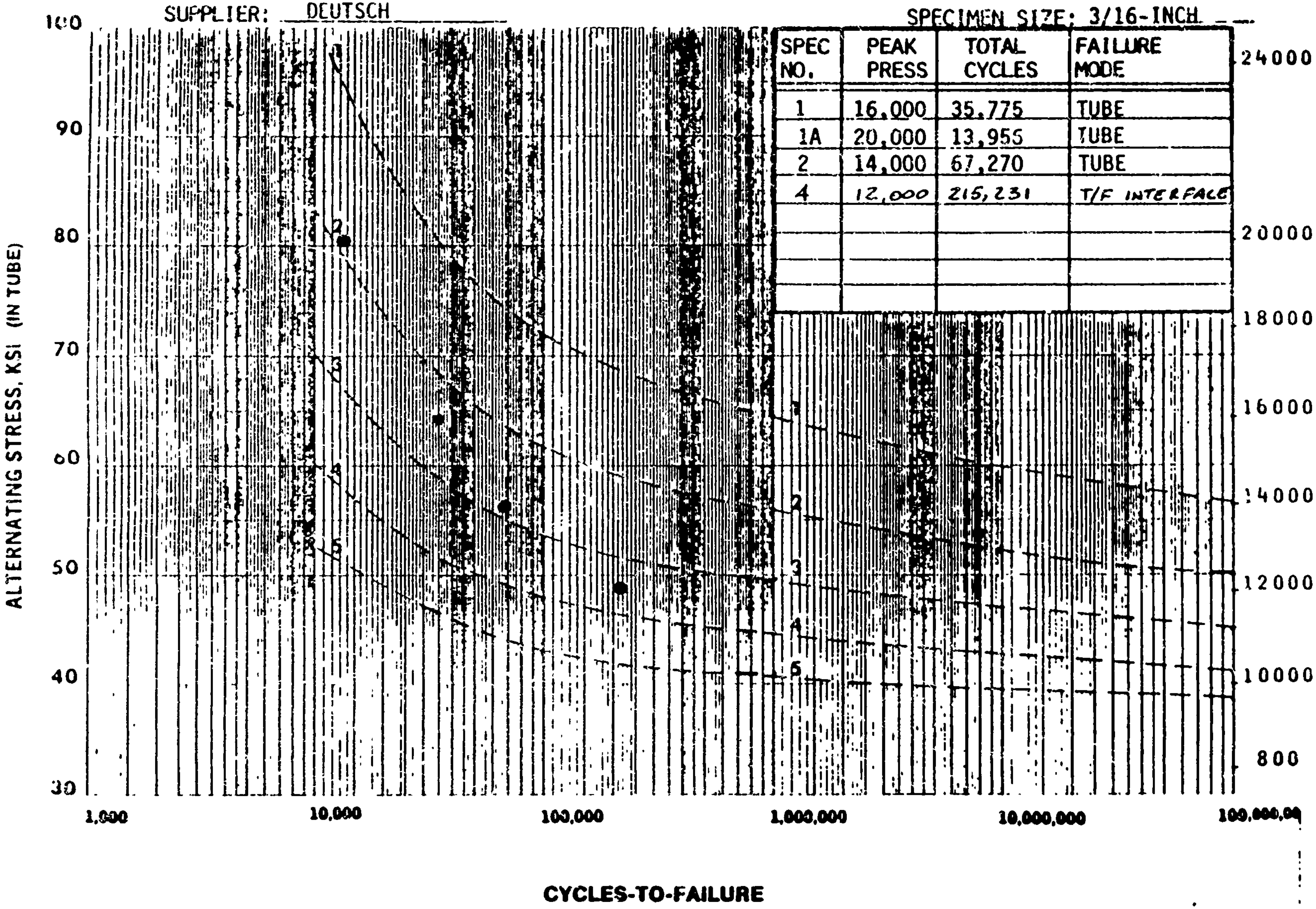
PERMANENT FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: DEUTSCH

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	16,000	35,775	TUBE
1A	20,000	13,955	TUBE
2	14,000	67,270	TUBE
4	12,000	215,231	T/F INTERFACE



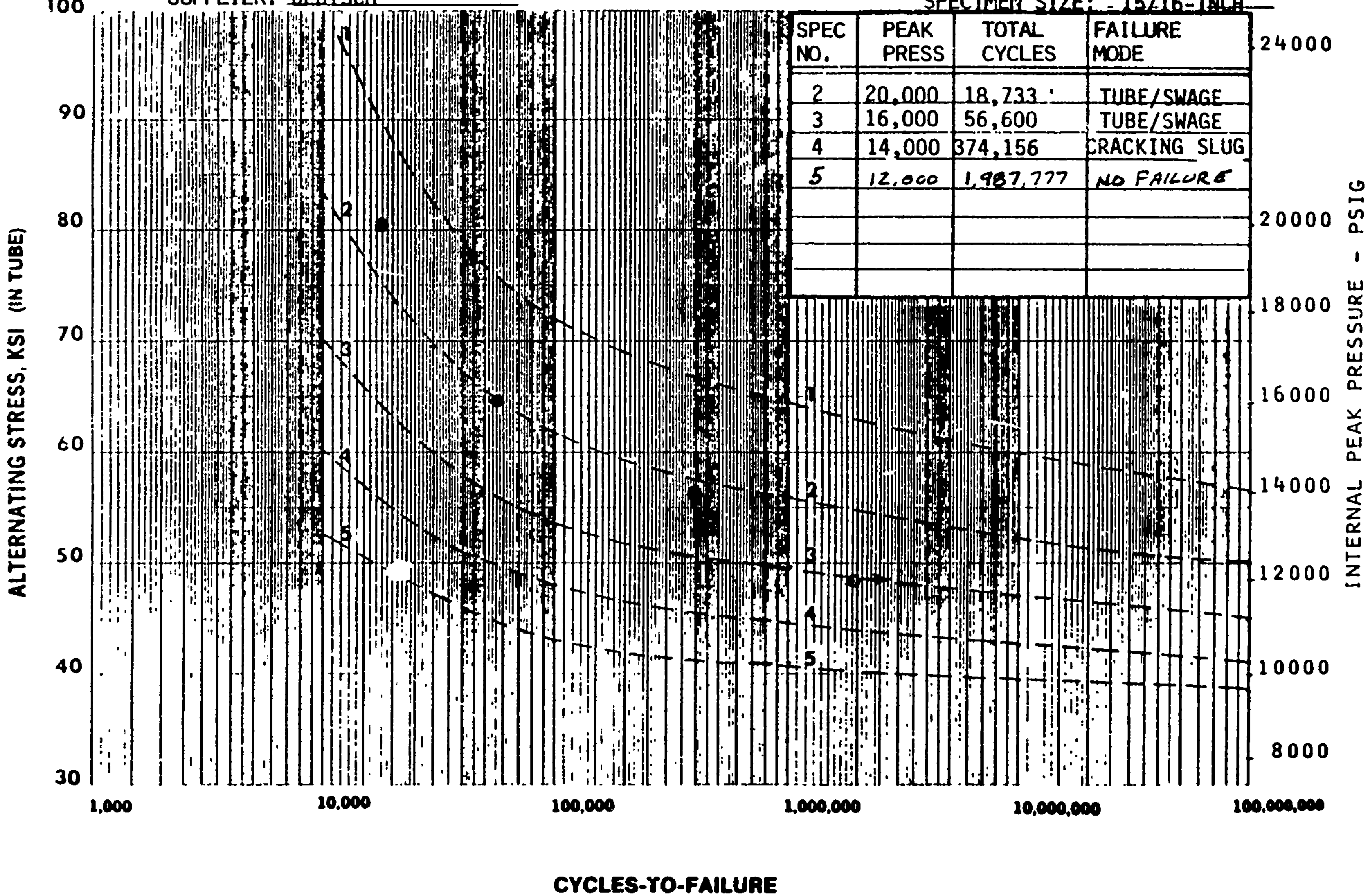
PERMANENT FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: DEUTSCH

SPECIMEN SIZE: 15/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
2	20,000	18,733	TUBE/SWAGE
3	16,000	56,600	TUBE/SWAGE
4	14,000	374,156	CRACKING SLUG
5	12,000	1,987,777	NO FAILURE



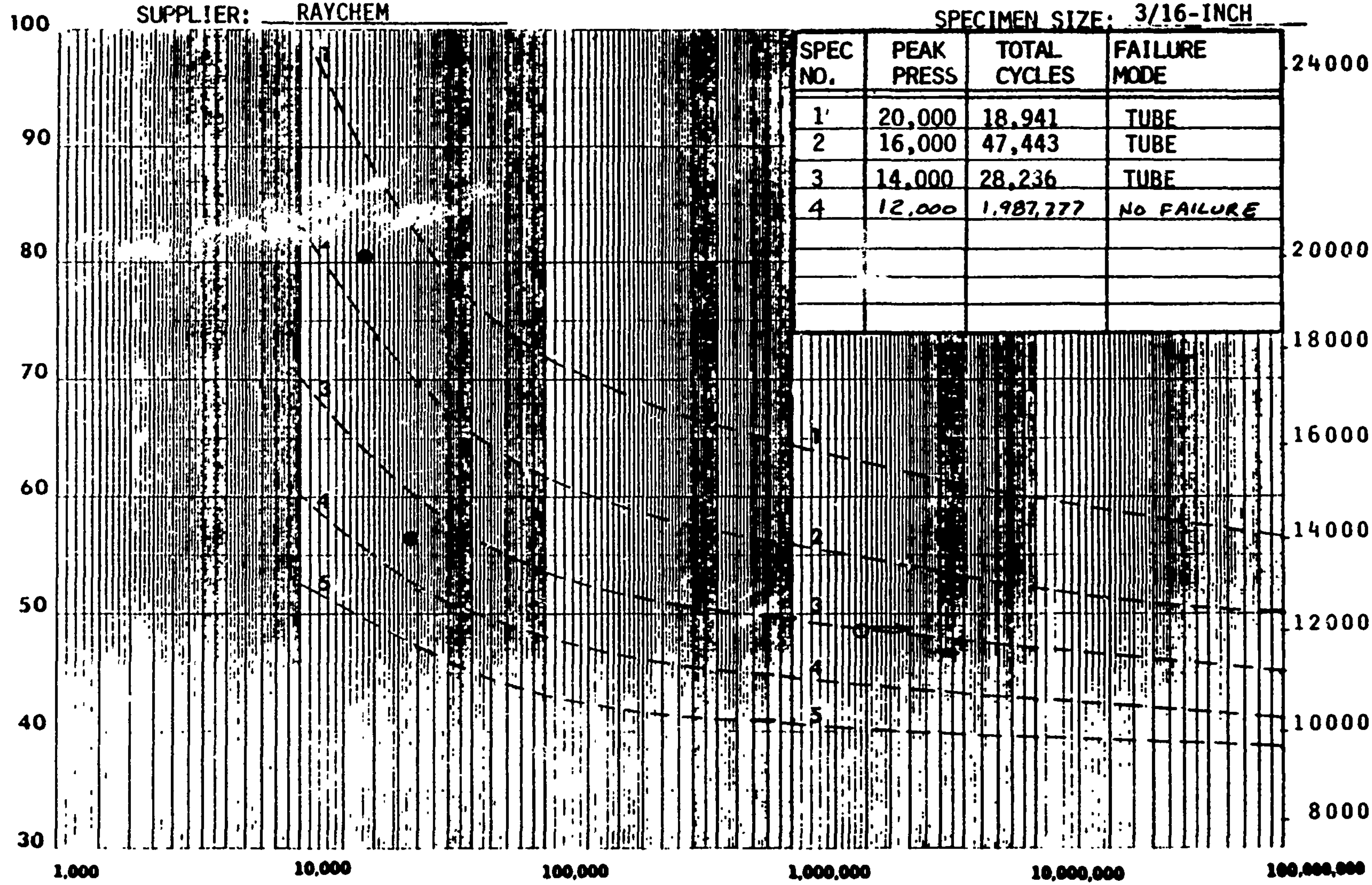
PERMANENT FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: RAYCHEM

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	20,000	18,941	TUBE
2	16,000	47,443	TUBE
3	14,000	28,236	TUBE
4	12,000	1,987,277	NO FAILURE



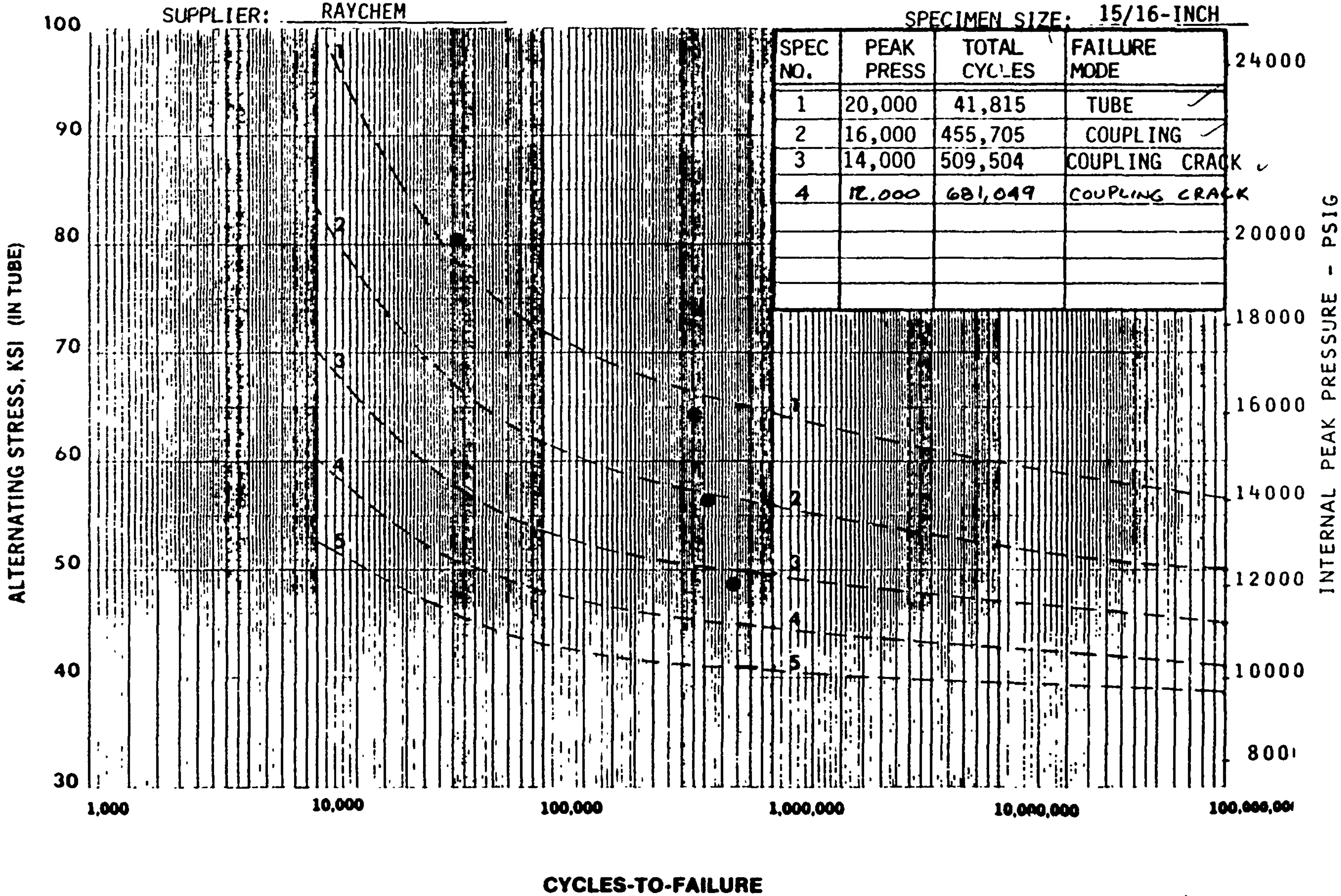
PERMANENT FITTINGS

PRESSURE IMPULSE RESULTS

SUPPLIER: RAYCHEM

SPECIMEN SIZE: 15/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	20,000	41,815	TUBE
2	16,000	455,705	COUPLING
3	14,000	509,504	COUPLING CRACK
4	12,000	681,049	COUPLING CRACK



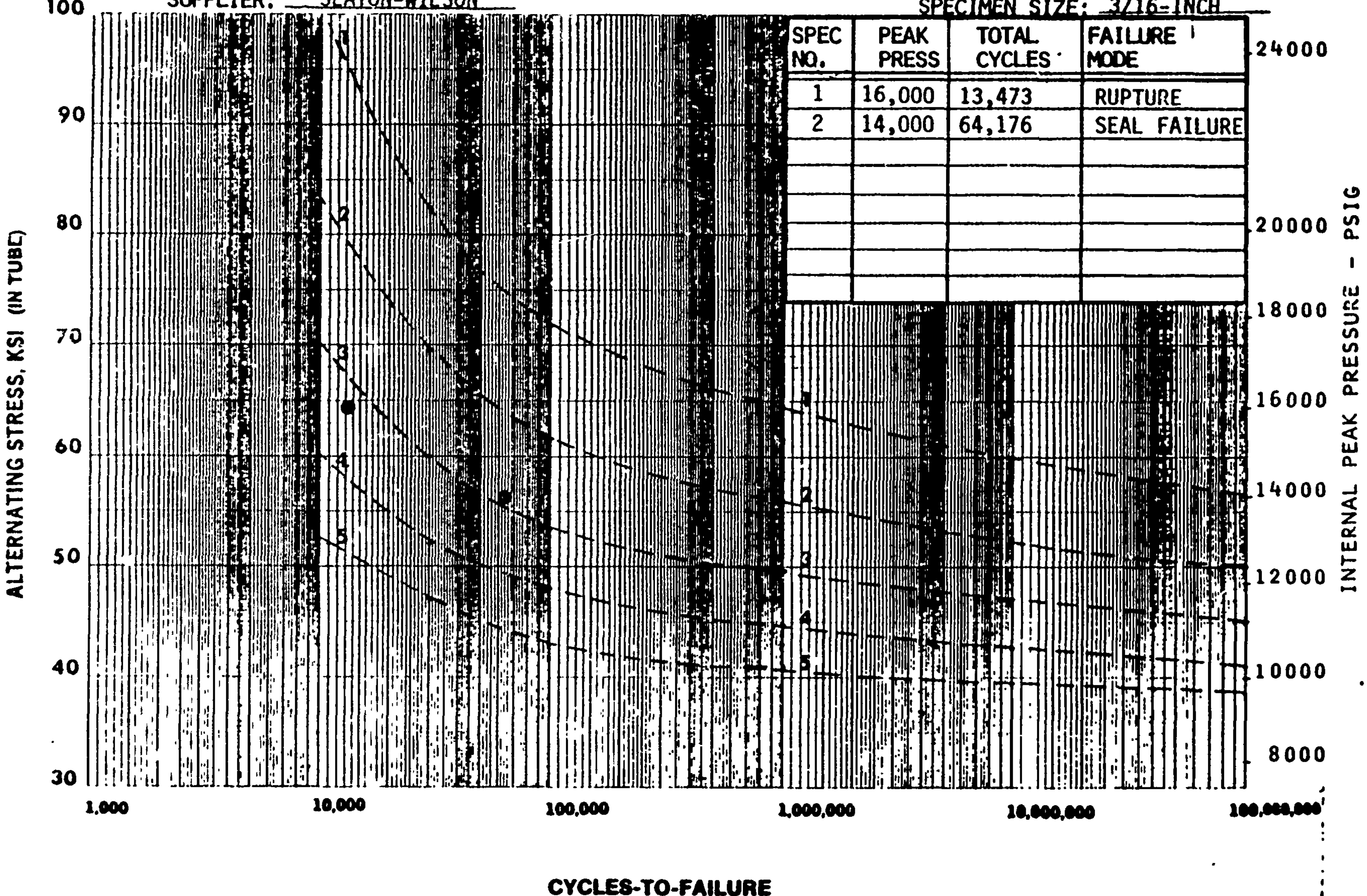
QUICK DISCONNECT

PRESSURE IMPULSE RESULTS

SUPPLIER: SEATON-WILSON

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	16,000	13,473	RUPTURE
2	14,000	64,176	SEAL FAILURE



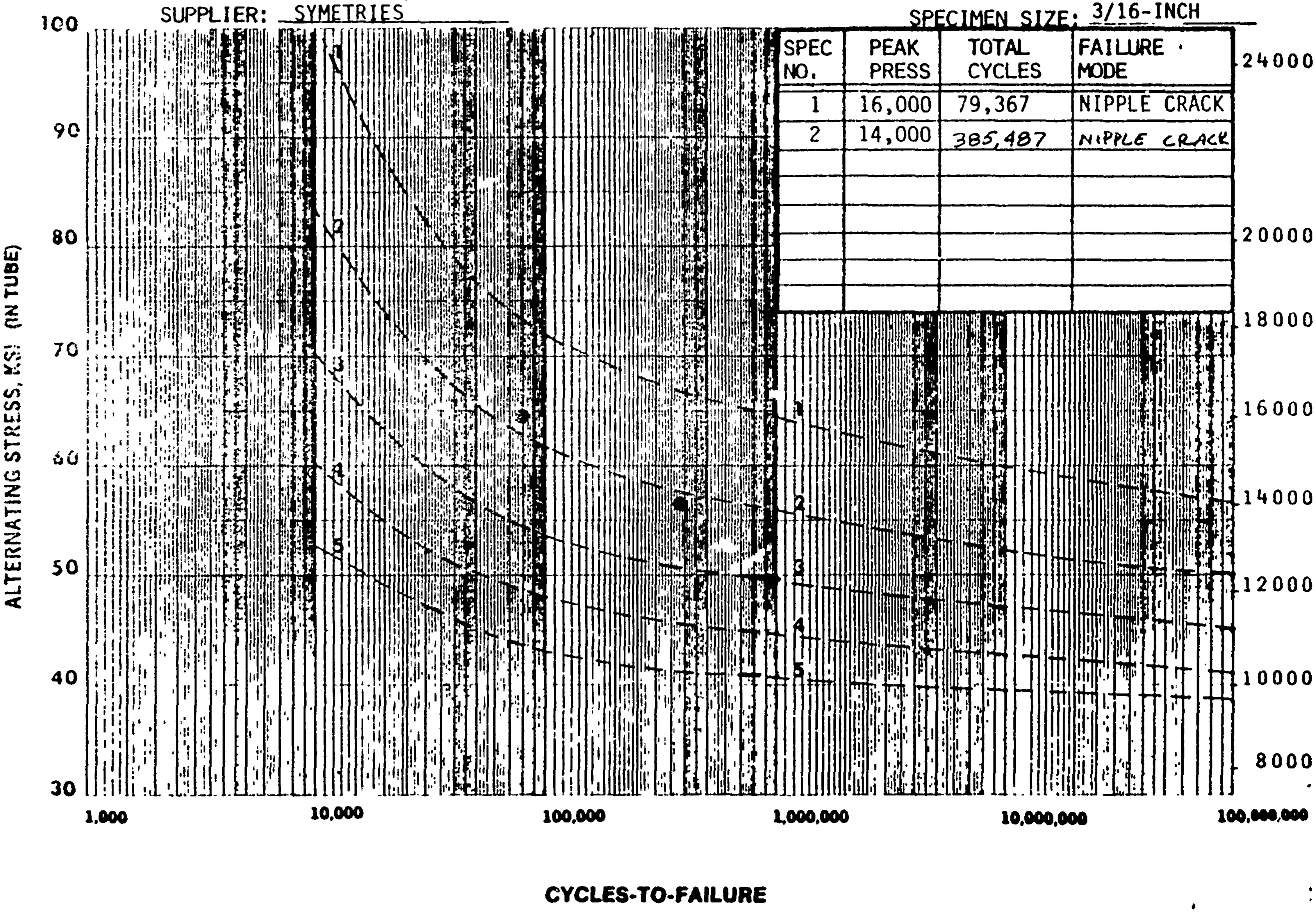
QUICK DISCONNECTS

PRESSURE IMPULSE RESULTS

SUPPLIER: SYMETRIES

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	16,000	79,367	NIPPLE CRACK
2	14,000	385,487	NIPPLE CRACK



SWIVELS

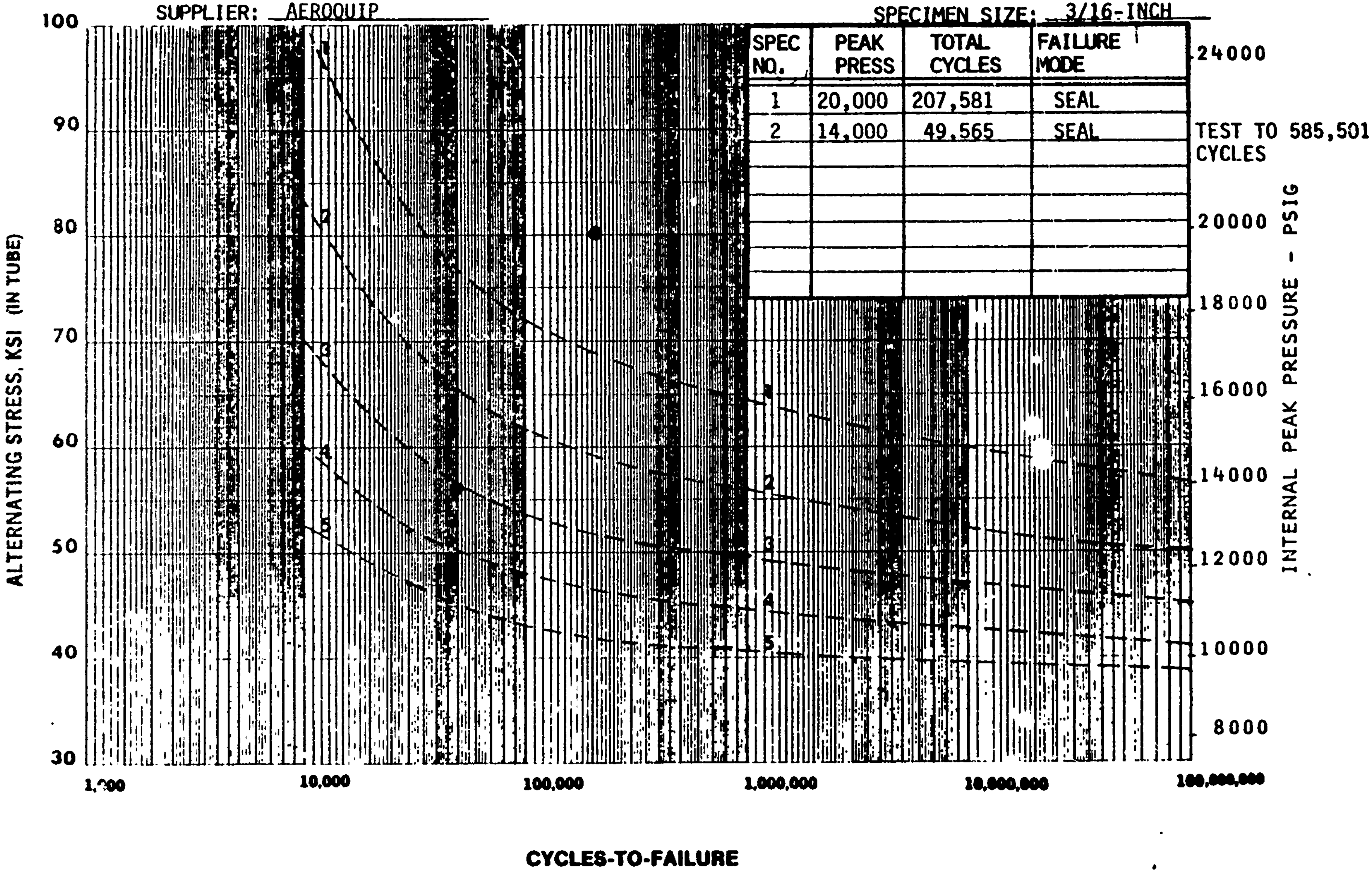
PRESSURE IMPULSE RESULTS

SUPPLIER: AEROQUIP

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	20,000	207,581	SEAL
2	14,000	49,565	SEAL

TEST TO 585,501 CYCLES



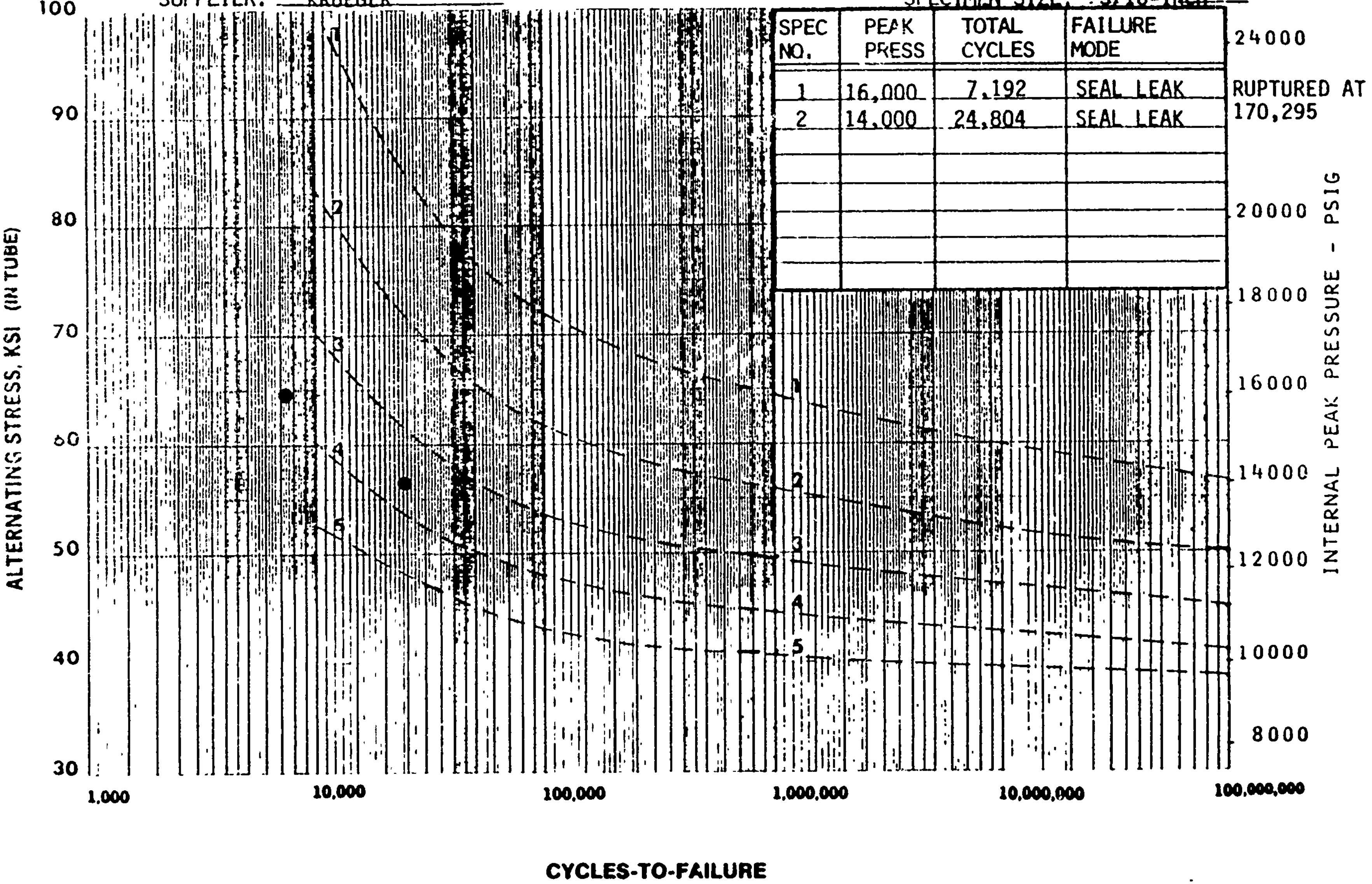
SWIVELS

PRESSURE IMPULSE RESULTS

SUPPLIER: KRUEGER

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	16,000	7,192	SEAL LEAK
2	14,000	24,804	SEAL LEAK



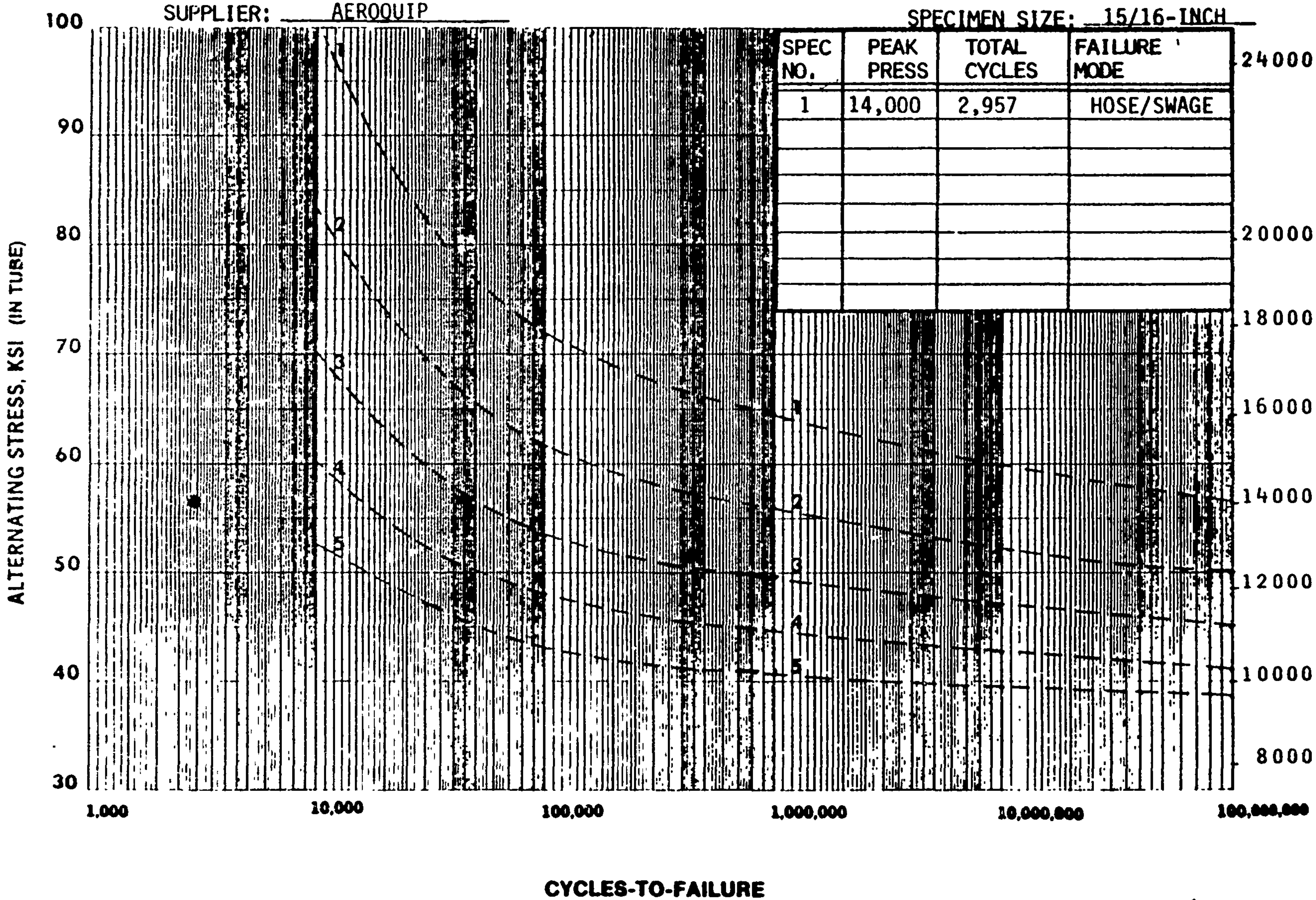
HOSE ASSEMBLIES

PRESSURE IMPULSE RESULTS

SUPPLIER: AEROQUIP

SPECIMEN SIZE: 15/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	14,000	2,957	HOSE/SWAGE



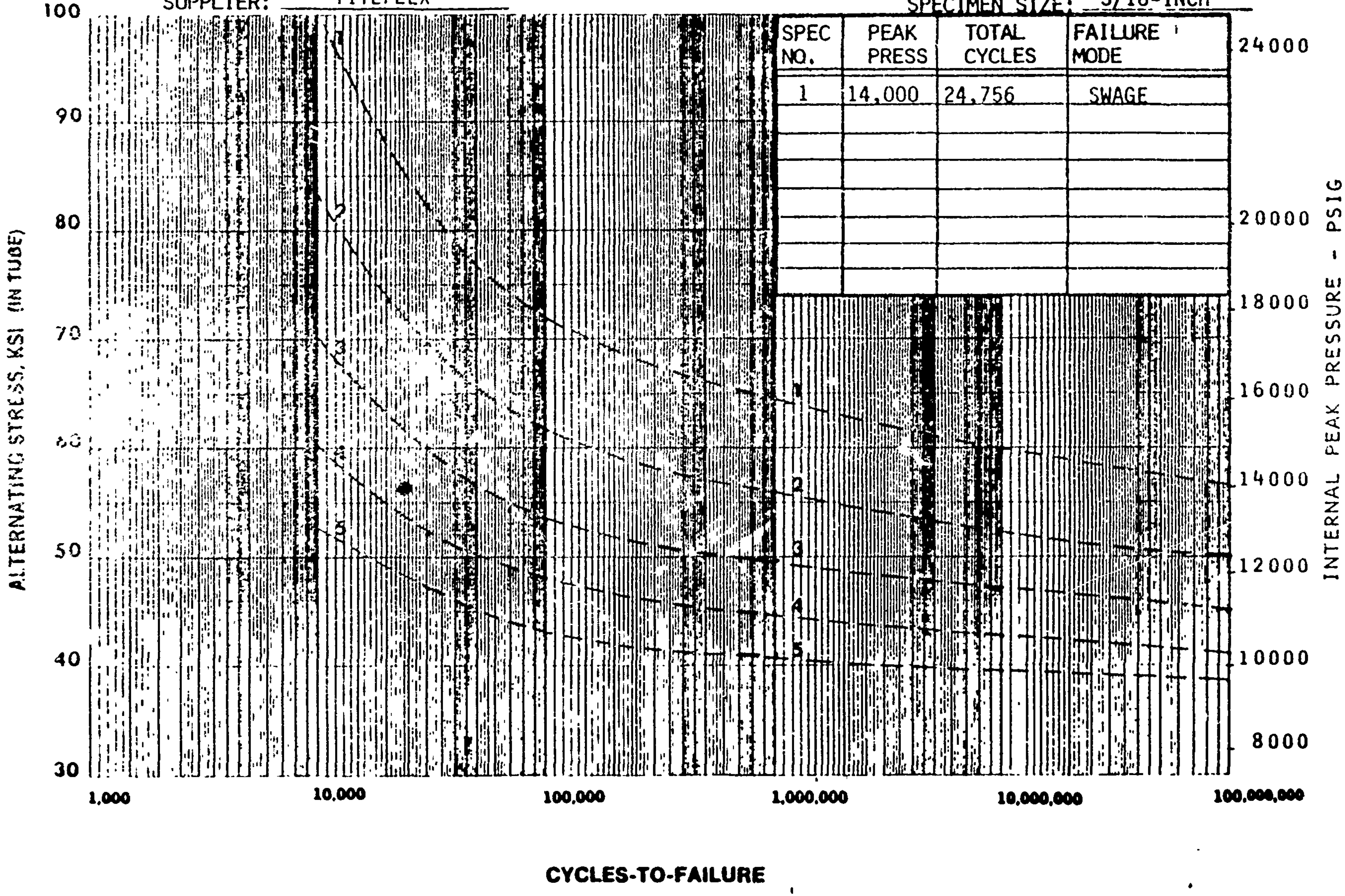
HOSE ASSEMBLIES

PRESSURE IMPULSE RESULTS

SUPPLIER: TITEFLEX

SPECIMEN SIZE: 3/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	14,000	24,756	SWAGE



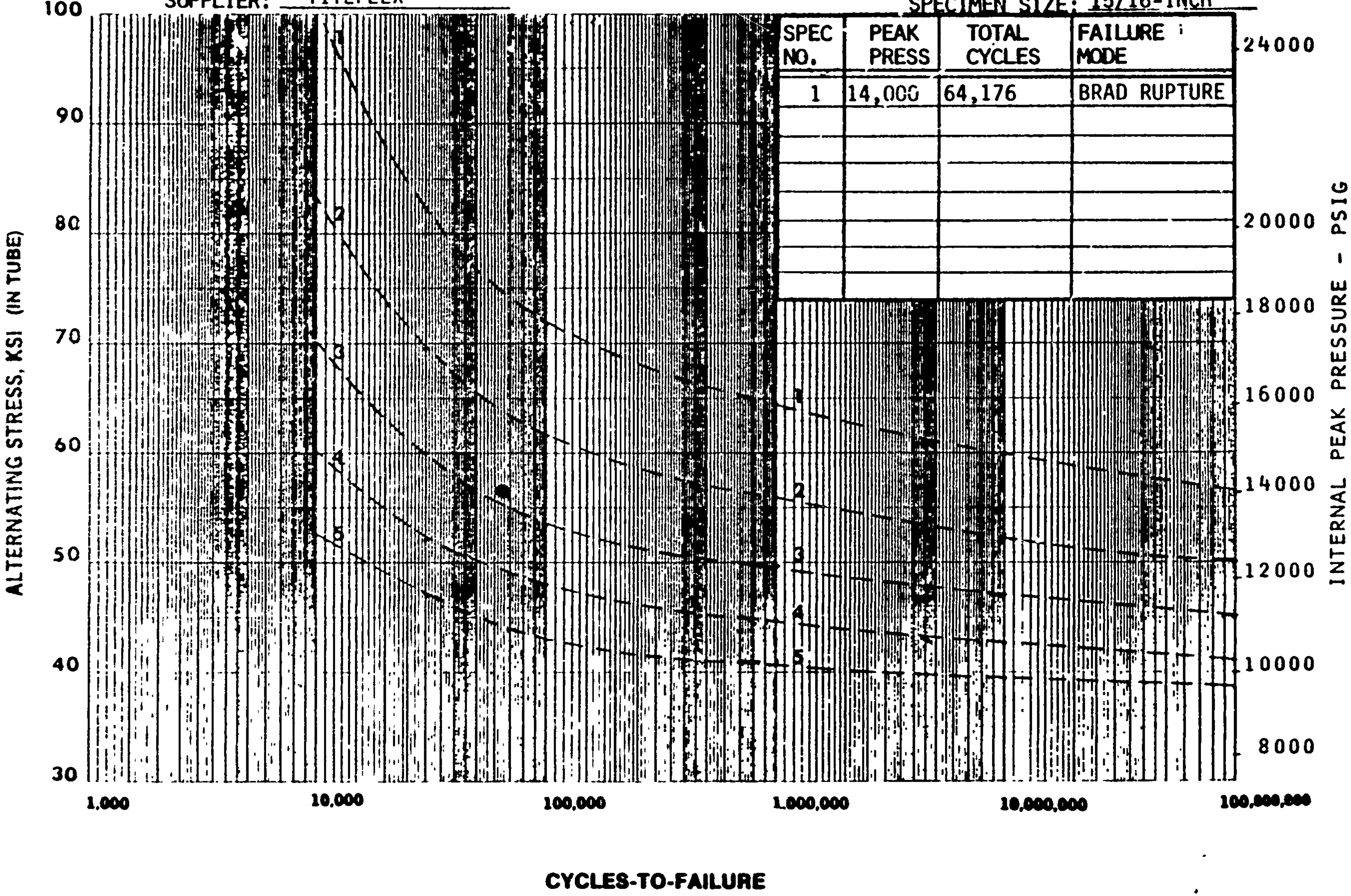
HOSE ASSEMBLIES

PRESSURE IMPULSE RESULTS

SUPPLIER: TITEFLEX

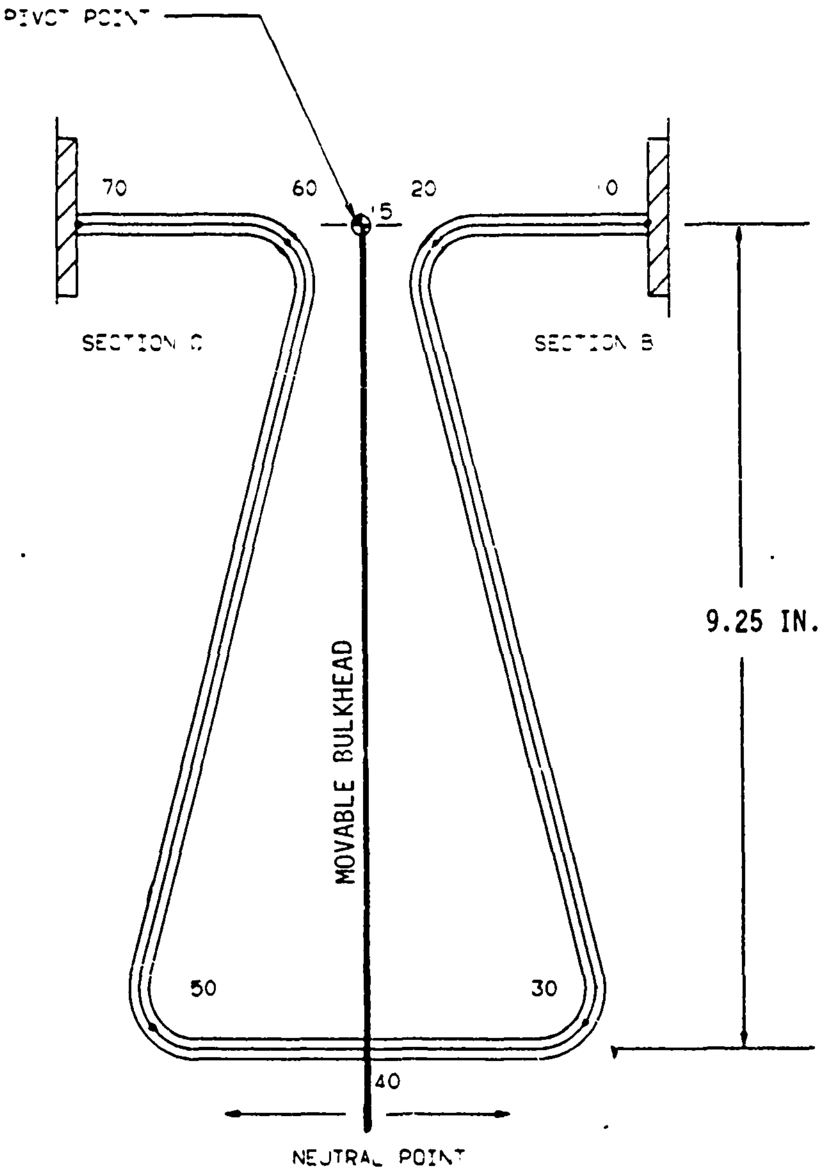
SPECIMEN SIZE: 15/16-INCH

SPEC NO.	PEAK PRESS	TOTAL CYCLES	FAILURE MODE
1	14,000	64,176	BRAD RUPTURE



APPENDIX C

Z-TUBE STRESS ANALYSIS



NOTE: ANGULAR ROTATION OF BULKHEAD = ±0.026 INCH RADIUS

Figure B-1. Computer Printout of 3/16-Inch O.D. Tube

```
#LIST ZTUBE2
ZTUBE2      16:43 DEC 14,'87

00100HIGH PRESSURE DEMONST[illegible]ROR
00110HPSD8000-1
00130AMBIENT TEMP.
00140OPTIONS
00150 TPW
00160MATERIAL PROPERTY
00170^18 70 15. .3 5.3 .162 .00075
00180^18 70 15. .3 5.3 .162 .00075
00190PIPE PROPERTY
00200^1 0.1875 0.021
00205^2 10. .5
00210LAYOUT
00220L10 KA M18 P1 CT=70,P=8000,SG=.87
00230F10 T20 KI X-0-12.00 B0.5625
00240T30 KI X0-10.00 Y-0-9.25 B0.5625
00250T40 X-0-12.00
00260T50 KI X-0-12.00 B0.5625
00270T60 KI X0-10.00 Y0-9.25 B0.5625
00280T70 KA X-0-12.00
00290F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,1.5)
00300NEXT
00310RERUN
00320LAYOUT
00330F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,-1.5)
```

COMMAND
?STRESS

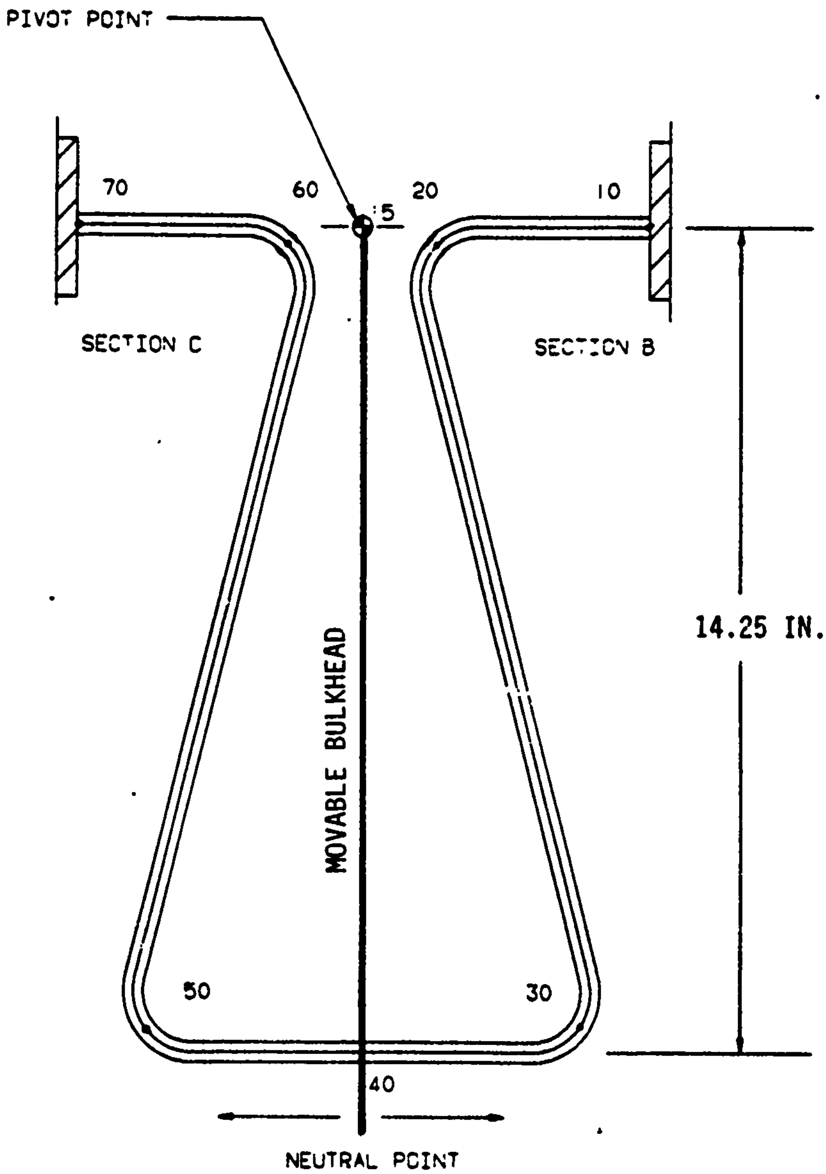
CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	-1	0	0	1.00	0	1.00	4392	4392
* U								
20 * N	-1	0	0	1.00	0	1.00	17050	17050
20 * B	-1	0	0	1.00	0	1.00	17050	17050
* E								
20 * N	0	0	0	1.00	0	1.00	16792	16792
* D								
20 *	0	0	0	1.00	0	1.00	15058	15058
20 * R	0	0	0	1.00	0	1.00	15058	15058
* U								
30 * N	0	0	0	1.00	0	1.00	13339	13339
30 * B	0	0	0	1.00	0	1.00	13339	13339
* E								
30 * N	0	0	0	1.00	0	1.00	15082	15082
* D								
30 *	-1	0	0	1.00	0	1.00	15302	15302
30 * R	-1	0	0	1.00	0	1.00	15302	15302
* U								
40 * N	-1	0	0	1.00	0	1.00	1229	1229
40 * R	0	0	0	1.00	0	1.00	2197	2197
* U								
50 * N	0	0	0	1.00	0	1.00	13514	13514
50 * B	0	0	0	1.00	0	1.00	13514	13514
* E								
50 * N	0	0	0	1.00	0	1.00	13263	13263
* D								
50 *	0	0	0	1.00	0	1.00	11674	11674
50 * R	0	0	0	1.00	0	1.00	11674	11674
* U								
60 * N	0	0	0	1.00	0	1.00	14215	14215
60 * B	0	0	0	1.00	0	1.00	14215	14215
* E								
60 * N	0	0	0	1.00	0	1.00	15813	15813
* D								
60 *	0	0	0	1.00	0	1.00	16026	16026
60 * R	0	0	0	1.00	0	1.00	16026	16026
* U								
70 * N	0	0	0	1.00	0	1.00	3294	3294
40 * R	0	0	0	1.00	0	1.00	0	0
* U								
15 * N	264	0	6	1.00	0	1.00	1	1

?STRESS

CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	0	0	0	1.00	0	1.00	3294	3294
* U								
20 * N	0	0	0	1.00	0	1.00	16026	16026
20 * B	0	0	0	1.00	0	1.00	16026	16026
* E								
20 * N	0	0	0	1.00	0	1.00	15813	15813
* D								
20 *	0	0	0	1.00	0	1.00	14215	14215
20 * R	0	0	0	1.00	0	1.00	14215	14215
* U								
30 * N	0	0	0	1.00	0	1.00	11674	11674
30 * B	0	0	0	1.00	0	1.00	11674	11674
* E								
30 * N	0	0	0	1.00	0	1.00	13263	13263
* D								
30 *	0	0	0	1.00	0	1.00	13514	13514
30 * R	0	0	0	1.00	0	1.00	13514	13514
* U								
40 * N	0	0	0	1.00	0	1.00	2197	2197
40 * R	-1	0	0	1.00	0	1.00	1229	1229
* U								
50 * N	-1	0	0	1.00	0	1.00	15302	15302
50 * B	-1	0	0	1.00	0	1.00	15302	15302
* E								
50 * N	0	0	0	1.00	0	1.00	15082	15082
* D								
50 *	0	0	0	1.00	0	1.00	13339	13339
50 * R	0	0	0	1.00	0	1.00	13339	13339
* U								
60 * N	0	0	0	1.00	0	1.00	15058	15058
60 * B	0	0	0	1.00	0	1.00	15058	15058
* E								
60 * N	0	0	0	1.00	0	1.00	16792	16792
* D								
60 *	-1	0	0	1.00	0	1.00	17050	17050
60 * R	-1	0	0	1.00	0	1.00	17050	17050
* U								
70 * N	-1	0	0	1.00	0	1.00	4392	4392
40 * R	0	0	0	1.00	0	1.00	0	0
* U								
15 * N	264	0	-6	1.00	0	1.00	1	1



NOTE: ANGULAR ROTATION OF BULKHEAD = ±0.026 INCH RADIUS

Figure B-2. Computer Printout of 5/16-Inch O.D. Tube

```
#LIST ZTUBE3
ZTUBE3     16:44 DEC 14,'87

00100HIGH PRESSURE DEMONSTRAROR
00110HPSD8000-1
00130AMBIENT TEMP.
00140OPTIONS
00150 TPW
00160MATERIAL PROPERTY
00170^18 70 15. .3 5.3 .162 .00075
00180^18 70 15. .3 5.3 .162 .00075
00190PIPE PROPERTY
00200^1 0.3125 0.034
00205^2 10. .5
00210LAYOUT
00220L10 KA M18 P1 CT=70,P=8000,SG=.87
00230F10 T20 KI X-0-12.00 B0.9375
00240T30 KI X0-10.00 Y-0-14.75 B0.9375
00250T40 X-0-12.00
00260T50 KI X-0-12.00 B0.9375
00270T60 KI X0-10.00 Y0-14.75 B0.9375
00280T70 KA X-0-12.00
00290F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,1.5)
00300NEXT
00310RERUN
00320LAYOUT
00330F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,-1.5)
```

COMMAND
?STRESS

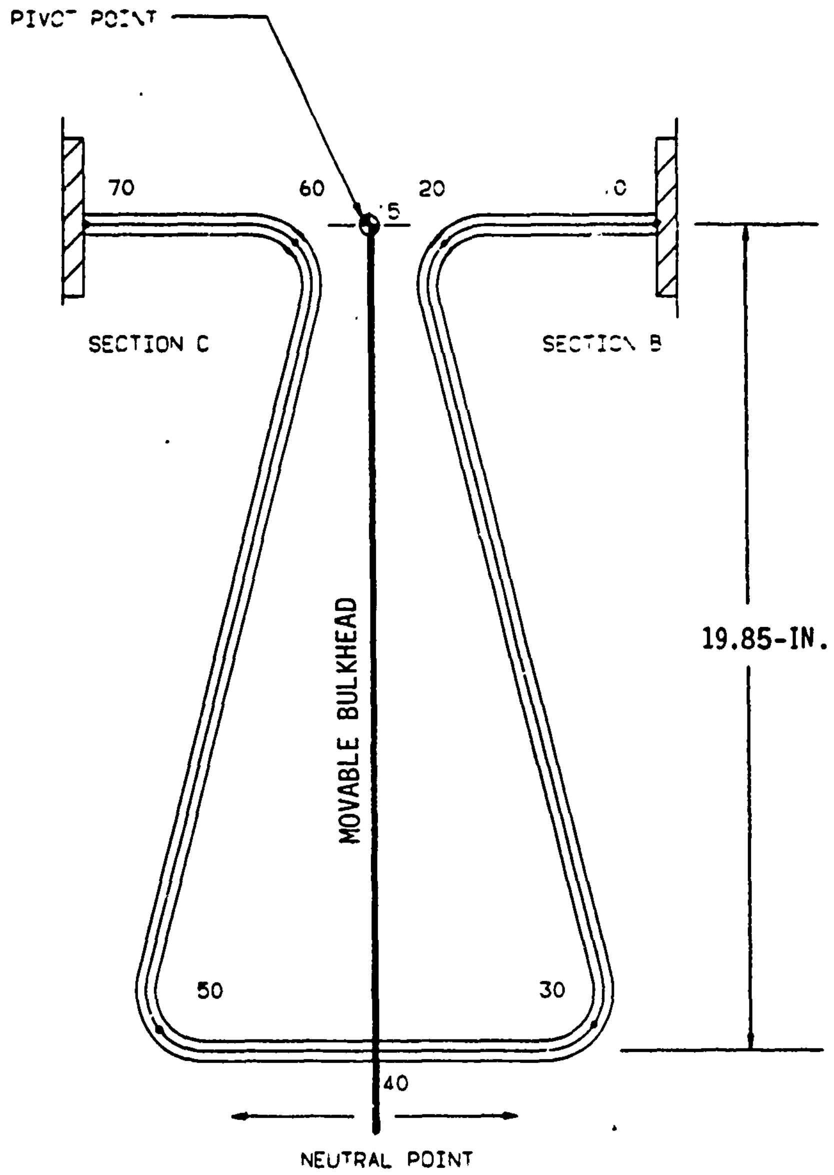
CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE------ BENDING MOMENT (FT-LBS)	SIF	------OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	-2	0	0	1.00	0	1.00	2774	2774
* U								
20 * N	-2	0	0	1.00	-2	1.00	16593	16593
20 * B	-2	0	2	1.00	0	1.00	16593	16593
* E								
20 * N	-3	0	2	1.00	0	1.00	17011	17011
* D								
20 *	0	0	2	1.00	0	1.00	15550	15550
20 * R	0	0	0	1.00	2	1.00	15550	15550
* U								
30 * N	0	0	0	1.00	-1	1.00	12665	12665
30 * B	0	0	1	1.00	0	1.00	12665	12665
* E								
30 * N	-3	0	2	1.00	0	1.00	14128	14128
* D								
30 *	-2	0	2	1.00	0	1.00	13662	13662
30 * R	-2	0	0	1.00	2	1.00	13662	13662
* U								
40 * N	-2	0	0	1.00	0	1.00	1139	1139
40 * R	2	0	0	1.00	0	1.00	549	549
* U								
50 * N	2	0	0	1.00	-1	1.00	11610	11610
50 * B	2	0	-1	1.00	0	1.00	11610	11610
* E								
50 * N	3	0	-1	1.00	0	1.00	11981	11981
* D								
50 *	0	0	-1	1.00	0	1.00	10699	10699
50 * R	0	0	0	1.00	1	1.00	10699	10699
* U								
60 * N	0	0	0	1.00	-2	1.00	14137	14137
60 * B	0	0	-2	1.00	0	1.00	14137	14137
* E								
60 * N	3	0	-2	1.00	0	1.00	15422	15422
* D								
60 *	2	0	-2	1.00	0	1.00	15003	15003
60 * R	2	0	0	1.00	2	1.00	15003	15003
* U								
70 * N	2	0	0	1.00	0	1.00	1860	1860
40 * R	0	0	0	1.00	0	1.00	0	0
* U								
15 * N	265	0	16	1.00	0	1.00	4	4

COMMAND
?STRESS

CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	2	0	0	1.00	0	1.00	1860	1860
* U								
20 * N	2	0	0	1.00	2	1.00	15003	15003
20 * B	2	0	-2	1.00	0	1.00	15003	15003
* E								
20 * N	3	0	-2	1.00	0	1.00	15422	15422
* D								
20 *	0	0	-2	1.00	0	1.00	14137	14137
20 * R	0	0	0	1.00	-2	1.00	14137	14137
* U								
30 * N	0	0	0	1.00	1	1.00	10699	10699
30 * B	0	0	-1	1.00	0	1.00	10699	10699
* E								
30 * N	3	0	-1	1.00	0	1.00	11981	11981
* D								
30 *	2	0	-1	1.00	0	1.00	11610	11610
30 * R	2	0	0	1.00	-1	1.00	11610	11610
* U								
40 * N	2	0	0	1.00	0	1.00	549	549
40 * R	-2	0	0	1.00	0	1.00	1139	1139
* U								
50 * N	-2	0	0	1.00	2	1.00	13662	13662
50 * B	-2	0	2	1.00	0	1.00	13662	13662
* E								
50 * N	-3	0	2	1.00	0	1.00	14127	14127
* D								
50 *	0	0	1	1.00	0	1.00	12665	12665
50 * R	0	0	0	1.00	-1	1.00	12665	12665
* U								
60 * N	0	0	0	1.00	2	1.00	15550	15550
60 * B	0	0	2	1.00	0	1.00	15550	15550
* E								
60 * N	-3	0	2	1.00	0	1.00	17011	17011
* D								
60 *	-2	0	2	1.00	0	1.00	16593	16593
60 * R	-2	0	0	1.00	-2	1.00	16593	16593
* U								
70 * N	-2	0	0	1.00	0	1.00	2774	2774
40 * R	0	0	0	1.00	0	1.00	0	0
* U								
15 * N	265	0	-16	1.00	0	1.00	4	4



NOTE: ANGULAR ROTATION OF BULKHEAD = ±0.026-INCH

Figure B-3. Computer Printout of 7/16-Inch O.D. Tube

```
LIST ZTUBE4
ZTUBE4     16:56 DEC 14,'87

00100HIGH PRESSURE DEMONSTRAROR
00110HPSD8000-1
00130AMBIENT TEMP.
00140OPTIONS
00150 TPW
00160MATERIAL PROPERTY
00170^18 70 15. .3 5.3 .162 .00075
00180^18 70 15. .3 5.3 .162 .00075
00190PIPE PROPERTY
00200^1 0.4375 0.049
00205^2 10. .5
00210LAYOUT
00220L10 KA M18 P1 CT=70,P=8000,SG=.87
00230F10 T20 KI X-0-12.00 B1.3125
00240T30 KI X0-10.00 Y-0-19.85 B1.3125
00250T40 X-0-12.00
00260T50 KI X-0-12.00 B1.3125
00270T60 KI X0-10.00 Y0-19.85 B1.3125
00280T70 KA X-0-12.00
00290F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,1.5)
00300NEXT
00310RERUN
00320LAYOUT
00330F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,-1.5)
```

?STRESS

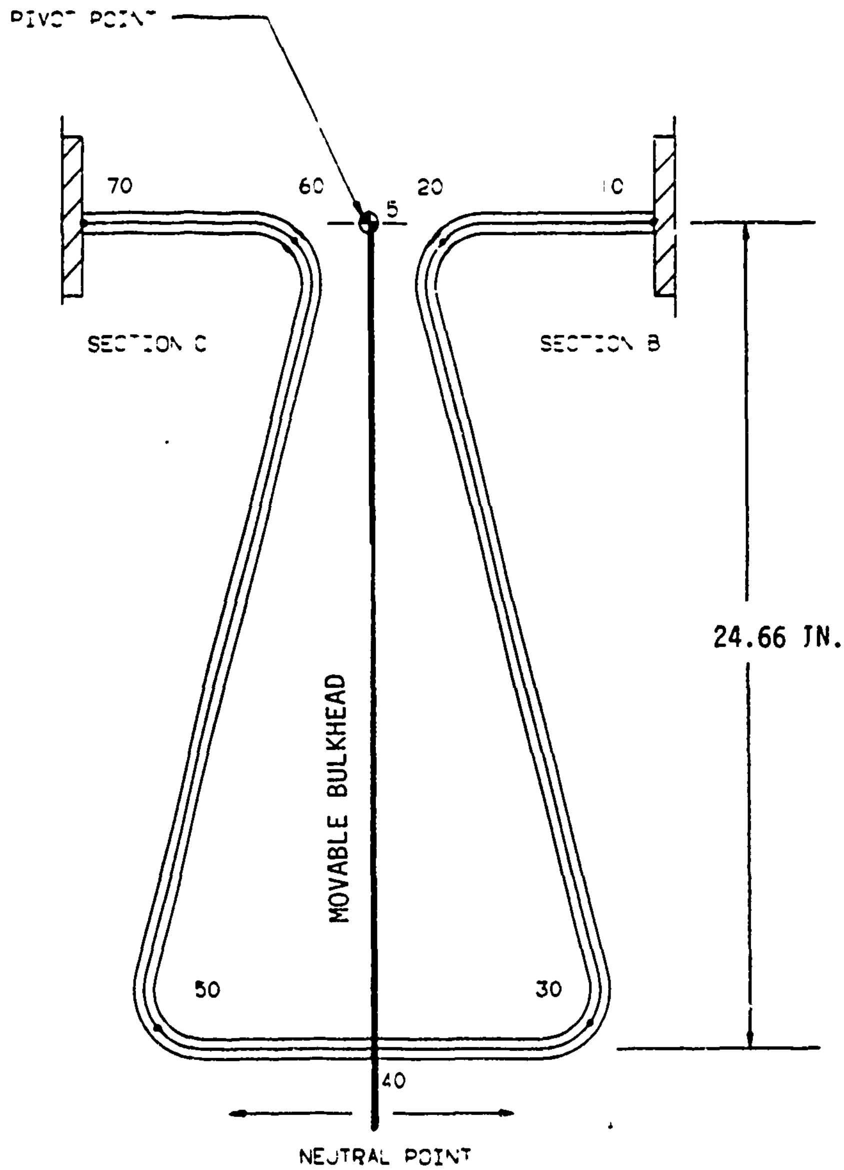
CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R * U	-5	0	0	1.00	0	1.00	1007	1007
20 * N	-5	0	0	1.00	-6	1.00	15944	15944
20 * B * E	-5	0	6	1.00	0	1.00	15944	15944
20 * N * D	-9	0	7	1.00	0	1.00	17048	17048
20 *	-4	0	6	1.00	0	1.00	15898	15898
20 * R * U	-4	0	0	1.00	6	1.00	15898	15898
30 * N	-5	0	0	1.00	-5	1.00	12124	12124
30 * B * E	-5	0	5	1.00	0	1.00	12124	12124
30 * N * D	-9	0	5	1.00	0	1.00	13270	13270
30 *	-5	0	5	1.00	0	1.00	12107	12107
30 * R * U	-5	0	0	1.00	5	1.00	12107	12107
40 * N	-5	0	0	1.00	-1	1.00	3612	3612
40 * R * U	4	0	0	1.00	1	1.00	3334	3334
50 * N	4	0	0	1.00	-4	1.00	9987	9987
50 * B * E	4	0	-4	1.00	0	1.00	9987	9987
50 * N * D	8	0	-4	1.00	0	1.00	11003	11003
50 *	4	0	-4	1.00	0	1.00	10037	10037
50 * R * U	4	0	0	1.00	4	1.00	10037	10037
60 * N	4	0	0	1.00	-6	1.00	14243	14243
60 * B * E	4	0	-6	1.00	0	1.00	14243	14243
60 * N * D	8	0	-6	1.00	0	1.00	15206	15206
60 *	4	0	-6	1.00	0	1.00	14131	14131
60 * R * U	4	0	0	1.00	6	1.00	14131	14131
70 * N	4	0	0	1.00	0	1.00	26	26
40 * R * U	1	0	3	1.00	0	1.00	0	0
15 * N	265	0	32	1.00	0	1.00	9	9

COMMAND
?STRESS

CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	4	0	0	1.00	0	1.00	26	26
* U								
20 * N	4	0	0	1.00	6	1.00	14131	14131
20 * B	4	0	-6	1.00	0	1.00	14131	14131
* E								
20 * N	8	0	-6	1.00	0	1.00	15206	15206
* D								
20 *	4	0	-6	1.00	0	1.00	14243	14243
20 * R	4	0	0	1.00	-6	1.00	14243	14243
* U								
30 * N	4	0	0	1.00	4	1.00	10037	10037
30 * B	4	0	-4	1.00	0	1.00	10037	10037
* E								
30 * N	8	0	-4	1.00	0	1.00	11003	11003
* D								
30 *	4	0	-4	1.00	0	1.00	9987	9987
30 * R	4	0	0	1.00	-4	1.00	9987	9987
* U								
40 * N	4	0	0	1.00	1	1.00	3334	3334
40 * R	-5	0	0	1.00	-1	1.00	3612	3612
* U								
50 * N	-5	0	0	1.00	5	1.00	12107	12107
50 * B	-5	0	5	1.00	0	1.00	12107	12107
* E								
50 * N	-9	0	5	1.00	0	1.00	13270	13270
* D								
50 *	-5	0	5	1.00	0	1.00	12124	12124
50 * R	-5	0	0	1.00	-5	1.00	12124	12124
* U								
60 * N	-4	0	0	1.00	6	1.00	15898	15898
60 * B	-4	0	6	1.00	0	1.00	15898	15898
* E								
60 * N	-9	0	7	1.00	0	1.00	17048	17048
* D								
60 *	-5	0	6	1.00	0	1.00	15944	15944
60 * R	-5	0	0	1.00	-6	1.00	15944	15944
* U								
70 * N	-5	0	0	1.00	0	1.00	1007	1007
40 * R	1	0	-3	1.00	0	1.00	0	0
* U								
15 * N	265	0	-32	1.00	0	1.00	9	9



NOTE: ANGULAR ROTATION OF BULKHEAD = ±0.026-INCH

Figure B-4. Computer Printout of 9/16-Inch O.D. Tube

```
#LIST ZTUBE5
ZTUBE5      16:44 DEC 14,'87

00100HIGH PRESSURE DEMONSTRAROR
00110HPSD8000-1
00130AMBIENT TEMP.
00140OPTIONS
00150 TPW
00160MATERIAL PROPERTY
00170 18 70 15. .3 5.3 .162 .00075
00180 18 70 15. .3 5.3 .162 .00075
00190PIPE PROPERTY
00200 1 0.5625 0.063
00205 2 10. .5
00210LAYOUT
00220L10 KA M18 P1 CT=70,P=8000,SG=.87
00230F10 T20 KI X-0-12.00 B1.6875
00240T30 KI X0-10.00 Y-0-24.66 B1.6875
00250T40 X-0-12.00
00260T50 HI X-0-12.00 B1.6875
00270T60 HI X0-10.00 Y0-24.66 B1.6875
00280T70 HA X-0-12.00
00290F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,1.5)
00300NEXT
00310RERUN
00320LAYOUT
00330F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,-1.5)
```

COMMAND
?STRESS

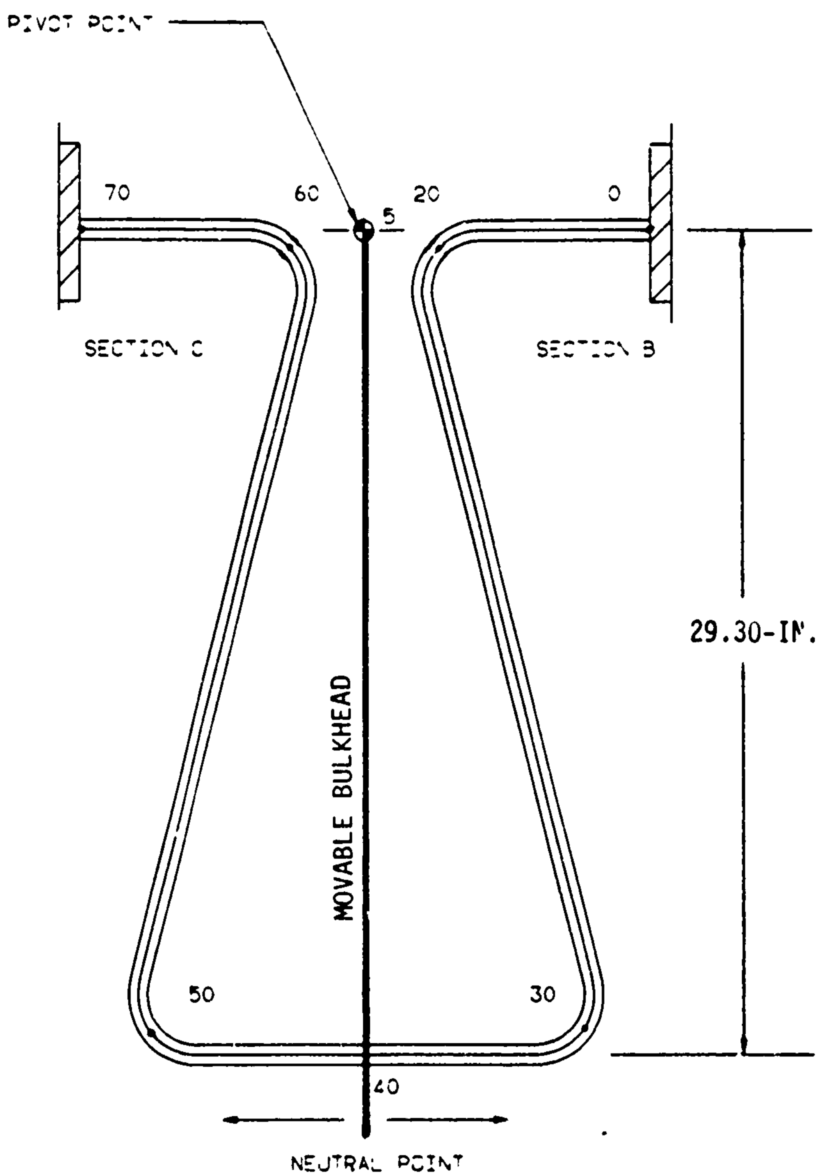
CALCULATD STRESS

DATA PNT.		AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10	* R	-7	0	0	1.00	0	1.00	964	964
	* U								
20	* N	-7	0	0	1.00	-14	1.00	15189	15189
20	* B	-7	0	14	1.00	0	1.00	15189	15189
	* E								
20	* N	-20	0	15	1.00	0	1.00	17067	17067
	* D								
20	*	-14	0	15	1.00	0	1.00	16252	16252
20	* R	-14	0	0	1.00	15	1.00	16252	16252
	* U								
30	* N	-15	0	0	1.00	-10	1.00	11753	11753
30	* B	-15	0	10	1.00	0	1.00	11753	11753
	* E								
30	* N	-20	0	11	1.00	0	1.00	12560	12560
	* D								
30	*	-7	0	9	1.00	0	1.00	10613	10613
30	* R	-7	0	0	1.00	9	1.00	10613	10613
	* U								
40	* N	-7	0	0	1.00	-5	1.00	6207	6207
40	* R	6	0	0	1.00	5	1.00	6099	6099
	* U								
50	* N	6	0	0	1.00	-7	1.00	8348	8348
50	* B	6	0	-7	1.00	0	1.00	8348	8348
	* E								
50	* N	17	0	-9	1.00	0	1.00	10077	10077
	* D								
50	*	13	0	-8	1.00	0	1.00	9452	9452
50	* R	13	0	0	1.00	8	1.00	9452	9452
	* U								
60	* N	13	0	0	1.00	-13	1.00	14314	14314
60	* B	13	0	-13	1.00	0	1.00	14314	14314
	* E								
60	* N	18	0	-13	1.00	0	1.00	14931	14931
	* D								
60	*	6	0	-12	1.00	0	1.00	13132	13132
60	* R	6	0	0	1.00	12	1.00	13132	13132
	* U								
70	* N	6	0	0	1.00	-1	1.00	1981	1981
40	* R	2	0	11	1.00	0	1.00	3	3
	* U								
15	* N	267	0	55	1.00	0	1.00	17	17

?STRESS

CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	6	0	0	1.00	-1	1.00	1981	1981
* U								
20 * N	6	0	0	1.00	12	1.00	13132	13132
20 * B	6	0	-12	1.00	0	1.00	13132	13132
* E								
20 * N	18	0	-13	1.00	0	1.00	14931	14931
* D								
20 *	13	0	-13	1.00	0	1.00	14314	14314
20 * R	13	0	0	1.00	-13	1.00	14314	14314
* U								
30 * N	13	0	0	1.00	8	1.00	9452	9452
30 * B	13	0	-8	1.00	0	1.00	9452	9452
* E								
30 * N	17	0	-9	1.00	0	1.00	10077	10077
* D								
30 *	6	0	-7	1.00	0	1.00	8348	8348
30 * R	6	0	0	1.00	-7	1.00	8348	8348
* U								
40 * N	6	0	0	1.00	5	1.00	6099	6099
40 * R	-7	0	0	1.00	-5	1.00	6207	6207
* U								
50 * N	-7	0	0	1.00	9	1.00	10613	10613
50 * B	-7	0	9	1.00	0	1.00	10613	10613
* E								
50 * N	-20	0	11	1.00	0	1.00	12560	12560
* D								
50 *	-15	0	10	1.00	0	1.00	11753	11753
50 * R	-15	0	0	1.00	-10	1.00	11753	11753
* U								
60 * N	-14	0	0	1.00	15	1.00	16252	16252
60 * B	-14	0	15	1.00	0	1.00	16252	16252
* E								
60 * N	-20	0	15	1.00	0	1.00	17067	17067
* D								
60 *	-7	0	14	1.00	0	1.00	15189	15189
60 * R	-7	0	0	1.00	-14	1.00	15189	15189
* U								
70 * N	-7	0	0	1.00	0	1.00	964	964
40 * R	2	0	-11	1.00	0	1.00	3	3
* U								
15 * N	267	0	-55	1.00	0	1.00	17	17



NOTE: ANGULAR ROTATION OF BULKHEAD = ±0.026-INCH

Figure B-5. Computer Printout o 11/16-Inch O.D. Tube

```
#LIST ZTUBE6
ZTUBE6      16:45 DEC 14,'87

00100HIGH PRESSURE DEMONSTRAROR
00110HPSD8000-1
00130AMBIENT TEMP.
00140OPTIONS
00150 TPW
00160MATERIAL PROPERTY
00170^18 70 15. .3 5.3 .162 .00075
00180^18 70 15. .3 5.3 .162 .00075
00190PIPE PROPERTY
00200^1 0.6875 0.076
00205^2 10. .5
00210LAYOUT
00220L10 KA M18 P1 CT=70,P=8000,SG=.87
00230F10 T20 KI X-0-12.00 B2.0625
00240T30 KI XO-10.00 Y-0-29.30 B2.0625
00250T40 X-0-12.00
00260T50 KI X-0-12.00 B2.0625
00270T60 KI XO-10.00 YO-29.30 B2.0625
00280T70 KA X-0-12.00
00290F40 T15 KA M2 P2 YO-38.33 CROT(0.0,0.0,1.5)
00300NEXT
00310RERUN
00320LAYOUT
00330F40 T15 KA M2 P2 YO-38.33 CROT(0.0,0.0,-1.5)
```

COMMAND
?STRESS

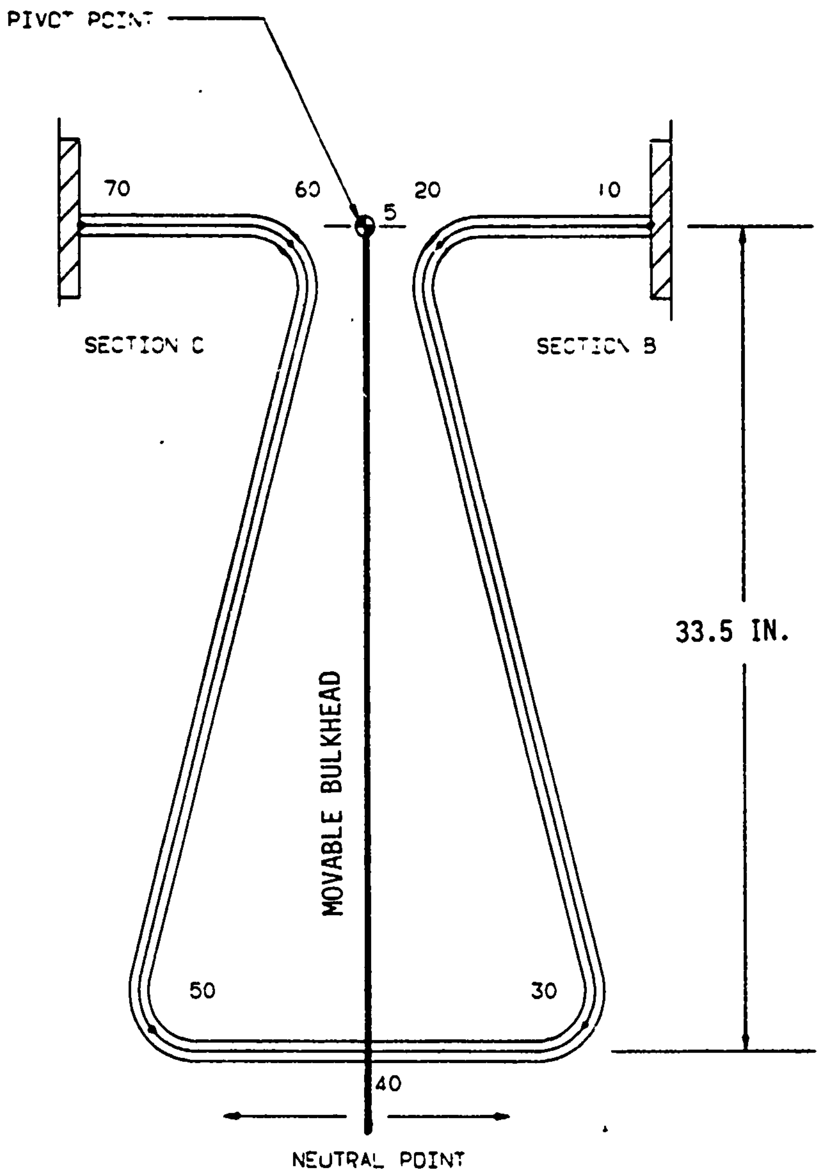
CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	-10	0	0	1.00	5	1.00	3110	3110
* U								
20 * N	-10	0	0	1.00	-23	1.00	14250	14250
20 * B	-10	0	23	1.00	0	1.00	14250	14250
* E								
20 * N	-37	0	28	1.00	0	1.00	17014	17014
* D								
20 *	-33	0	27	1.00	0	1.00	16577	16577
20 * R	-33	0	0	1.00	27	1.00	16577	16577
* U								
30 * N	-33	0	0	1.00	-19	1.00	11470	11470
30 * B	-33	0	19	1.00	0	1.00	11470	11470
* E								
30 * N	-38	0	19	1.00	0	1.00	11894	11894
* D								
30 *	-10	0	15	1.00	0	1.00	9051	9051
30 * R	-10	0	0	1.00	15	1.00	9051	9051
* U								
40 * N	-10	0	0	1.00	-14	1.00	8894	8894
40 * R	7	0	0	1.00	14	1.00	8850	8850
* U								
50 * N	7	0	0	1.00	-11	1.00	6613	6613
50 * B	7	0	-11	1.00	0	1.00	6613	6613
* E								
50 * N	32	0	-15	1.00	0	1.00	9141	9141
* D								
50 *	30	0	-14	1.00	0	1.00	8894	8894
50 * R	30	0	0	1.00	14	1.00	8894	8894
* U								
60 * N	30	0	0	1.00	-24	1.00	14318	14318
60 * B	30	0	-24	1.00	0	1.00	14318	14318
* E								
60 * N	33	0	-24	1.00	0	1.00	14554	14554
* D								
60 *	7	0	-20	1.00	0	1.00	11945	11945
60 * R	7	0	0	1.00	20	1.00	11945	11945
* U								
70 * N	7	0	0	1.00	-6	1.00	4103	4103
40 * R	5	0	29	1.00	0	1.00	9	9
* U								
15 * N	270	0	87	1.00	0	1.00	26	26

?STRESS

CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE------ BENDING MOMENT (FT-LBS)	SIF	------OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	7	0	0	1.00	-6	1.00	4103	4103
* U								
20 * N	7	0	0	1.00	20	1.00	11945	11945
20 * B	7	0	-20	1.00	0	1.00	11945	11945
* E								
20 * N	33	0	-24	1.00	0	1.00	14554	14554
* D								
20 *	30	0	-24	1.00	0	1.00	14318	14318
20 * R	30	0	0	1.00	-24	1.00	14318	14318
* U								
30 * N	30	0	0	1.00	14	1.00	8894	8894
30 * B	30	0	-14	1.00	0	1.00	8894	8894
* E								
30 * N	32	0	-15	1.00	0	1.00	9141	9141
* D								
30 *	7	0	-11	1.00	0	1.00	6613	6613
30 * R	7	0	0	1.00	-11	1.00	6613	6613
* U								
40 * N	7	0	0	1.00	14	1.00	8850	8850
40 * R	-10	0	0	1.00	-14	1.00	8894	8894
* U								
50 * N	-10	0	0	1.00	15	1.00	9051	9051
50 * B	-10	0	15	1.00	0	1.00	9051	9051
* E								
50 * N	-38	0	19	1.00	0	1.00	11894	11894
* D								
50 *	-33	0	19	1.00	0	1.00	11470	11470
50 * R	-33	0	0	1.00	-19	1.00	11470	11470
* U								
60 * N	-33	0	0	1.00	27	1.00	16577	16577
60 * B	-33	0	27	1.00	0	1.00	16577	16577
* E								
60 * N	-37	0	28	1.00	0	1.00	17014	17014
* D								
60 *	-10	0	23	1.00	0	1.00	14250	14250
60 * R	-10	0	0	1.00	-23	1.00	14250	14250
* U								
70 * N	-10	0	0	1.00	5	1.00	3109	3109
40 * R	5	0	-29	1.00	0	1.00	9	9
* U								
15 * N	270	0	-87	1.00	0	1.00	26	26



NOTE: ANGULAR ROTATION OF BULKHEAD = ±0.026-INCH

Figure B-6. Computer Printout of 13/16-Inch O.D. Tube

```
#LIST ZTUBE7
ZTUBE7      16:45 DEC 14,'87

00100HIGH PRESSURE DEMONSTRAROR
00110HPSD8000-1
00130AMBIENT TEMP.
00140OPTIONS
00150 TPW
00160MATERIAL PROPERTY
00170^18 70 15. .3 5.3 .162 .00075
00180^18 70 15. .3 5.3 .162 .00075
00190PIPE PROPERTY
00200^1 0.8125 0.089
00205^2 10. .5
00210LAYOUT
00220L10 KA M18 P1 CT=70,P=8000,SG=.87
00230F10 T20 KI X-0-12.00 B2.4375
00240T30 KI X0-10.00 Y-0-33.5 B2.4375
00250T40 X-0-12.00
00260T50 KI X-0-12.00 B2.4375
00270T60 KI X0-10.00 Y0-33.5 B2.4375
00280T70 KA X-0-12.00
00290F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,1.5)
00300NEXT
00310RERUN
00320LAYOUT
00330F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,-1.5)
```

COMMAND
?STRESS

CALCULATD STRESS

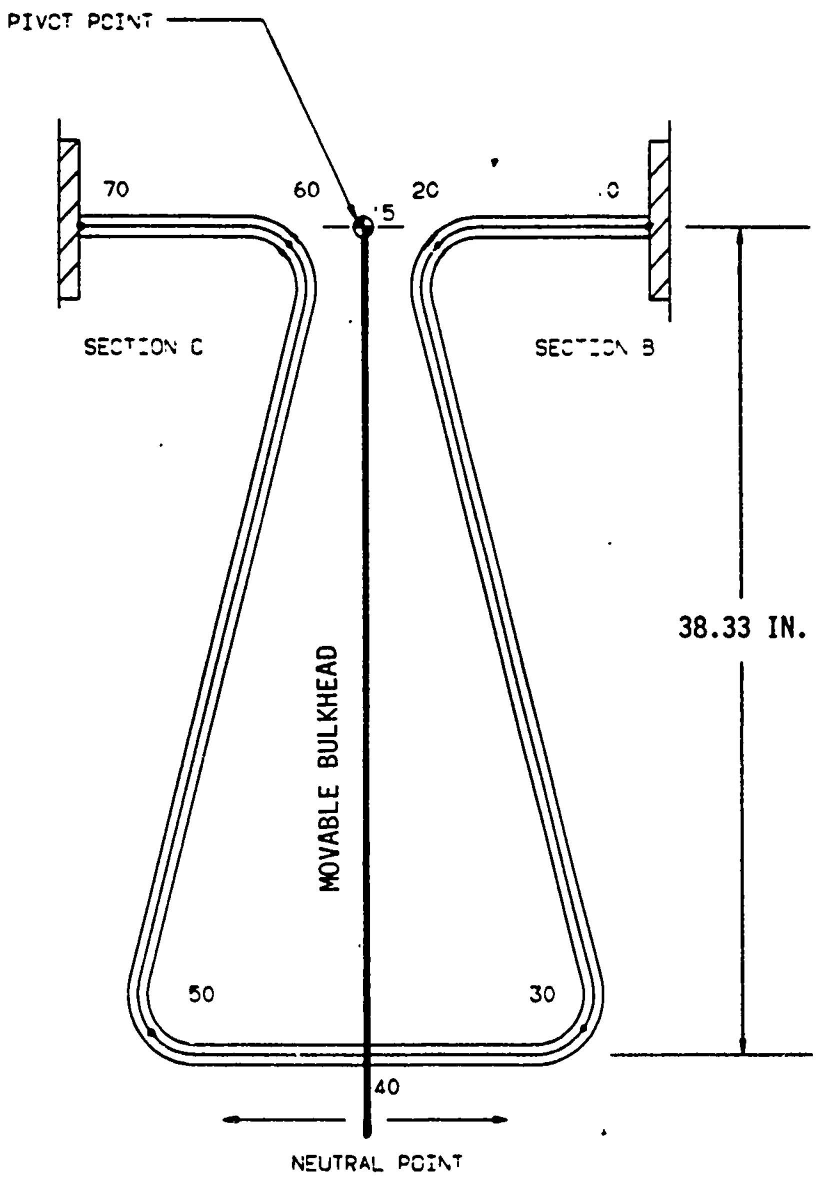
DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	-13	0	0	1.00	14	1.00	5281	5281
* U								
20 * N	-13	0	0	1.00	-36	1.00	13291	13291
20 * B	-13	0	36	1.00	0	1.00	13291	13291
* E								
20 * N	-64	0	47	1.00	0	1.00	17072	17072
* D								
20 *	-64	0	46	1.00	0	1.00	17028	17028
20 * R	-64	0	0	1.00	46	1.00	17028	17028
* U								
30 * N	-65	0	0	1.00	-31	1.00	11364	11364
30 * B	-65	0	31	1.00	0	1.00	11364	11364
* E								
30 * N	-65	0	31	1.00	0	1.00	11393	11393
* D								
30 *	-13	0	20	1.00	0	1.00	7522	7522
30 * R	-13	0	0	1.00	20	1.00	7522	7522
* U								
40 * N	-13	0	0	1.00	-31	1.00	11571	11571
40 * R	8	0	0	1.00	31	1.00	11560	11560
* U								
50 * N	8	0	0	1.00	-13	1.00	4938	4938
50 * B	8	0	-13	1.00	0	1.00	4938	4938
* E								
50 * N	55	0	-23	1.00	0	1.00	8381	8381
* D								
50 *	57	0	-23	1.00	0	1.00	8521	8521
50 * R	57	0	0	1.00	23	1.00	8521	8521
* U								
60 * N	58	0	0	1.00	-39	1.00	14467	14467
60 * B	58	0	-39	1.00	0	1.00	14467	14467
* E								
60 * N	56	0	-39	1.00	0	1.00	14311	14311
* D								
60 *	8	0	-29	1.00	0	1.00	10780	10780
60 * R	8	0	0	1.00	29	1.00	10780	10780
* U								
70 * N	8	0	0	1.00	-17	1.00	6240	6240
40 * R	10	0	63	1.00	0	1.00	19	19
* U								
15 * N	274	0	134	1.00	0	1.00	40	40

?STRESS

CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	8	0	0	1.00	-17	1.00	6240	6240
* U								
20 * N	8	0	0	1.00	29	1.00	10780	10780
20 * B	8	0	-29	1.00	0	1.00	10780	10780
* E								
20 * N	56	0	-39	1.00	0	1.00	14311	14311
* D								
20 *	58	0	-39	1.00	0	1.00	14467	14467
20 * R	58	0	0	1.00	-39	1.00	14467	14467
* U								
30 * N	57	0	0	1.00	23	1.00	8521	8521
30 * B	57	0	-23	1.00	0	1.00	8521	8521
* E								
30 * N	55	0	-23	1.00	0	1.00	8381	8381
* D								
30 *	8	0	-13	1.00	0	1.00	4938	4938
30 * R	8	0	0	1.00	-13	1.00	4938	4938
* U								
40 * N	8	0	0	1.00	31	1.00	11560	11560
40 * R	-13	0	0	1.00	-31	1.00	11571	11571
* U								
50 * N	-13	0	0	1.00	20	1.00	7522	7522
50 * B	-13	0	20	1.00	0	1.00	7522	7522
* E								
50 * N	-65	0	31	1.00	0	1.00	11393	11393
* D								
50 *	-65	0	31	1.00	0	1.00	11364	11364
50 * R	-65	0	0	1.00	-31	1.00	11364	11364
* U								
60 * N	-64	0	0	1.00	46	1.00	17028	17028
60 * B	-64	0	46	1.00	0	1.00	17028	17028
* E								
60 * N	-64	0	47	1.00	0	1.00	17072	17072
* D								
60 *	-13	0	36	1.00	0	1.00	13291	13291
60 * R	-13	0	0	1.00	-36	1.00	13291	13291
* U								
70 * N	-13	0	0	1.00	14	1.00	5281	5281
40 * R	10	0	-63	1.00	0	1.00	19	19
* U								
15 * N	274	0	-134	1.00	0	1.00	40	40

LOAD: T+P+W
COMMAND



NOTE: ANGULAR ROTATION OF BULKHEAD = ±0.036-INCH

Figure B-7. Computer Printout of 15/16-Inch O.D. Tube

```
#LIST ZTUBE1
ZTUBE1      16:43 DEC 14,'87

00100HIGH PRESSURE DEMONSTRAROR
00110HPSD8000-1
00130AMBIENT TEMP.
00140OPTIONS
00150 TPW
00160MATERIAL PROPERTY
00170 18 70 15. .3 5 [illegible] .162 .00075
00180 18 70 15. [illegible] .3 .162 .00075
00190PIPE PROPERT[illegible]
00200 1 0.9375 0.102
00205 2 10. .5
00210LAYOUT
00220L10 KA M18 P1 CT=70,P=8000,SG=.87
00230F10 T20 KI X-0-12.00 B2.8125
00240T30 KI X0-10.00 Y-0-38.33 B2.8125
00250T40 X-0-12.00
00260T50 KI X-0-12.00 B2.8125
00270T60 KI X0-10.00 Y0-38.33 B2.8125
00280T70 KA X-0-12.00
00290F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,1.5)
00300NEXT
00310RERUN
00320LAYOUT
00330F40 T15 KA M2 P2 Y0-38.33 CROT(0.0,0.0,-1.5)
```

?STRESS

CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	-14	0	0	1.00	32	1.00	7736	7736
* U								
20 * N	-14	0	0	1.00	-49	1.00	11696	11696
20 * B	-14	0	49	1.00	0	1.00	11696	11696
* E								
20 * N	-102	0	69	1.00	0	1.00	16575	16575
* D								
20 *	-110	0	71	1.00	0	1.00	17047	17047
20 * R	-110	0	0	1.00	71	1.00	17047	17047
* U								
30 * N	-112	0	0	1.00	-46	1.00	10974	10974
30 * B	-112	0	46	1.00	0	1.00	10974	10974
* E								
30 * N	-103	0	44	1.00	0	1.00	10482	10482
* D								
30 *	-14	0	23	1.00	0	1.00	5502	5502
30 * R	-14	0	0	1.00	23	1.00	5502	5502
* U								
40 * N	-14	0	0	1.00	-60	1.00	14406	14406
40 * R	8	0	0	1.00	60	1.00	14333	14333
* U								
50 * N	8	0	0	1.00	-11	1.00	2843	2843
50 * B	8	0	-11	1.00	0	1.00	2843	2843
* E								
50 * N	87	0	-30	1.00	0	1.00	7251	7251
* D								
50 *	98	0	-33	1.00	0	1.00	7879	7879
50 * R	98	0	0	1.00	33	1.00	7879	7879
* U								
60 * N	100	0	0	1.00	-59	1.00	14212	14212
60 * B	100	0	-59	1.00	0	1.00	14212	14212
* E								
60 * N	89	0	-57	1.00	0	1.00	13565	13565
* D								
60 *	8	0	-38	1.00	0	1.00	9056	9056
60 * R	8	0	0	1.00	38	1.00	9056	9056
* U								
70 * N	8	0	0	1.00	-36	1.00	8597	8597
40 * R	17	0	121	1.00	0	1.00	36	36
* U								
15 * N	281	0	192	1.00	0	1.00	58	58

STRESS

CALCULATD STRESS

DATA PNT.	AXIAL FORCE (LBS)	TORSIONAL MOMENT (FT-LBS)	---IN PLANE--- BENDING MOMENT (FT-LBS)	SIF	---OUT PLANE--- BENDING MOMENT (FT-LBS)	SIF	RESULTANT STRESS (PSI)	S(E) (PSI)
10 * R	8	0	0	1.00	-36	1.00	8598	8598
* U								
20 * N	8	0	0	1.00	38	1.00	9056	9056
20 * B	8	0	-38	1.00	0	1.00	9056	9056
* E								
20 * N	89	0	-57	1.00	0	1.00	13565	13565
* D								
20 *	100	0	-59	1.00	0	1.00	14213	14213
20 * R	100	0	0	1.00	-59	1.00	14213	14213
* U								
30 * N	98	0	0	1.00	33	1.00	7879	7879
30 * B	98	0	-33	1.00	0	1.00	7879	7879
* E								
30 * N	87	0	-30	1.00	0	1.00	7251	7251
* D								
30 *	8	0	-11	1.00	0	1.00	2843	2843
30 * R	8	0	0	1.00	-11	1.00	2843	2843
* U								
40 * N	8	0	0	1.00	60	1.00	14333	14333
40 * R	-14	0	0	1.00	-60	1.00	14406	14406
* U								
50 * N	-14	0	0	1.00	23	1.00	5502	5502
50 * B	-14	0	23	1.00	0	1.00	5502	5502
* E								
50 * N	-103	0	44	1.00	0	1.00	10482	10482
* D								
50 *	-112	0	46	1.00	0	1.00	10974	10974
50 * R	-112	0	0	1.00	-46	1.00	10974	10974
* U								
60 * N	-110	0	0	1.00	71	1.00	17047	17047
60 * B	-110	0	71	1.00	0	1.00	17047	17047
* E								
60 * N	-102	0	69	1.00	0	1.00	16575	16575
* D								
60 *	-14	0	49	1.00	0	1.00	11696	11696
60 * R	-14	0	0	1.00	-49	1.00	11696	11696
* U								
70 * N	-14	0	0	1.00	32	1.00	7735	7735
40 * R	17	0	-121	1.00	0	1.00	36	36
* U								
15 * N	281	0	-192	1.00	0	1.00	58	58

APPENDIX D

LINE SUPPORT DRAWING

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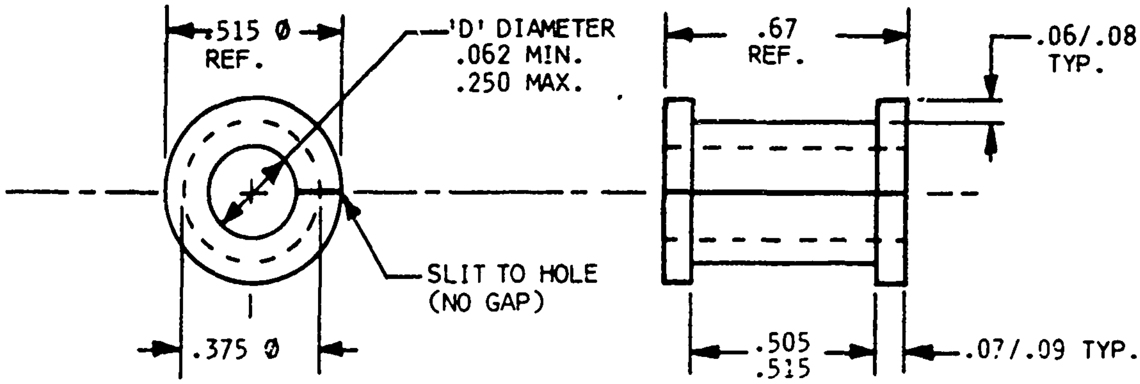
Rev	Description	By	Date	App.	Date
A	ADDED 'HB' MATERIAL, REV. DASH NO'S.	L.S.	4-17	[illegible]	4-7
B	ADDED NOTE - OTHER MATERIALS, ETC.	L.S.	[illegible]	[illegible]	[illegible]
C	ADDED 'WD' MATERIAL	L.S.	[illegible]	[illegible]	[illegible]
D	REDRAWN, ADDED SHT. (2), ADDED (-07), .515 Ø REF. WAS .50 Ø, .67 REF. WAS .69	M.W.	[illegible]	[illegible]	1-28



CODE	COMPOUND	SPEC.	DESCRIPTION
WD	TA9798		SILICONE, UNSUPPORTED, 60 DUROMETER, COLOR BROWN
NB	TA77-2	M85052/1	NITRILE BUTADIENE, 70 DUROMETER, COLOR YELLOW
HC	TA101	M85052/3	SILICONE, UNSUPPORTED, 70 DUROMETER, COLOR BLUE
HB	TA88	MIL-R-3065	SILICONE, UNSUPPORTED, 60 DUROMETER, COLOR PINK
HA	TA6711	BMS 1-63	SILICONE, UNSUPPORTED, 55 DUROMETER, COLOR WHITE
[illegible]	TA79-1	M85052/2	ETHYLENE PROPYLENE, 70 DUROMETER, COLOR PURPLE
CR	TA69	AMS 3209	NEOPRENE (CHLOROPRENE), 70 DUROMETDR, COLOR BLACK

MATERIAL OPTIONS

PART NUMBERING SYSTEM

BASIC PART NUMBER

MATERIAL CODE

'D' DIAMETER IN 1/16 INCH INCREMENTS (-04 MAX.) OR SPECIAL CONFIGURATION FROM SHT. (2)

TA03M57 HB 02 = 'HB' SILICONE INSERT WITH 'D' DIA. OF 1/8 INCH.

Unless otherwise specified

Tolerances	inches	mm
Fractions ±	1/16	1.59
.xxx ±	.010	0.25
.xx ±	.020	0.51
.x ±	.030	0.76

Angles ± 2°30'

Drawn by L.E. SHERMAN Date 7-77

Chkd by Date 7-77

Eng Date 1-28-87

QA Date 1-28-8[illegible]

Mfg Date 1-28-87

CRITON TA MFG.

375 West Arden Avenue
PO Box 2500
Glendale California 91209-2500

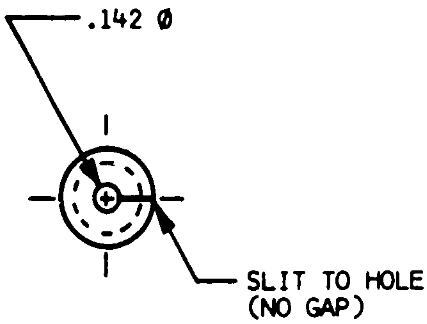
Drwg Title

INSERT

Size A Mfg Code 84971 Drawing No **TA03M57**

Sheet **1** of **2**

REVISIONS			
LTR	DESCRIPTION	APPROVED	DATE



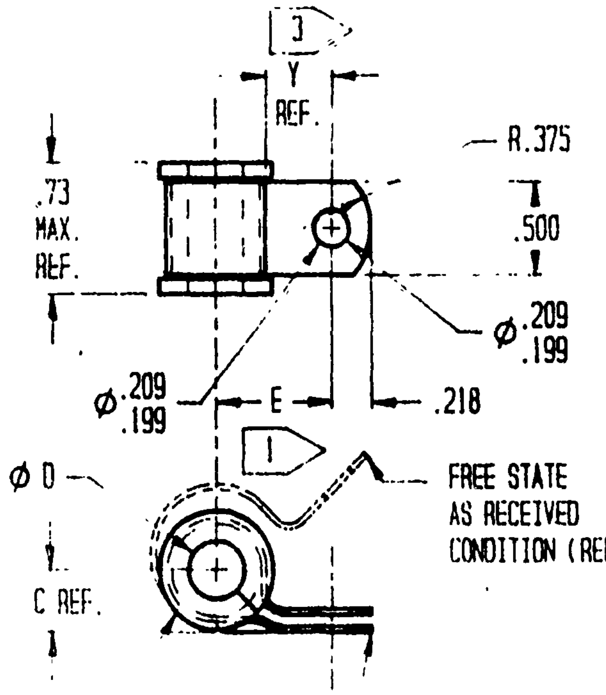
TA03M57 (XX) 07

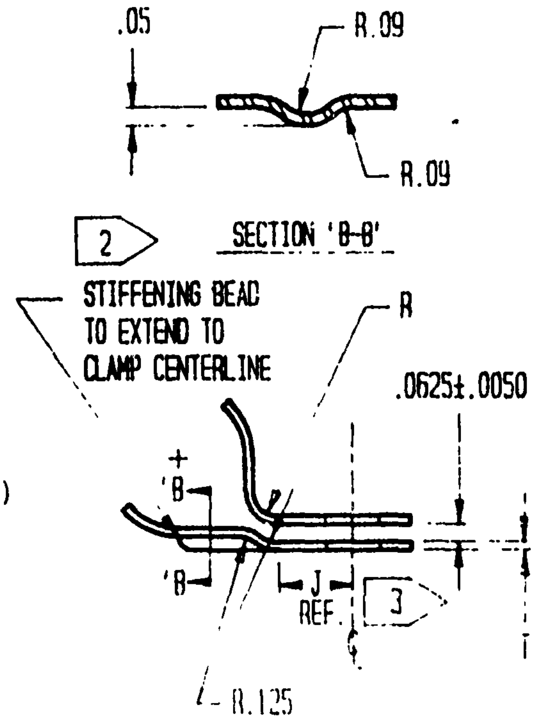
SIZE	CODE IDENT NO	DRAWING NO	
A	84971	TA03M57	
SCALE NONE		SHEET 2	OF 2

MILITARY SPECIFICATION SHEET

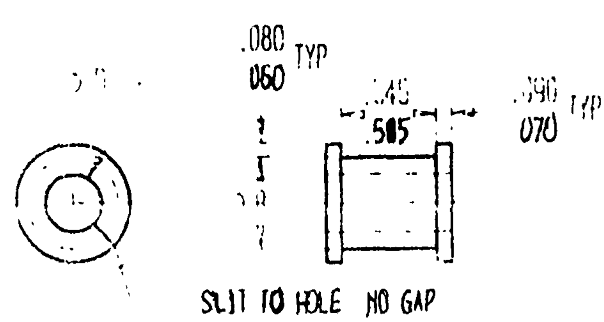
CLAMP, INSERT, LOOP, TUBE, 17-7PH CRES., 500° F

THE COMPLETE REQUIREMENTS FOR ACQUIRING THE CLAMPS DESCRIBED HEREIN SHALL CONSIST OF THIS DOCUMENT AND THE LATEST ISSUE IN EFFECT OF SPECIFICATION MIL-C-85052.





DETAIL -I- (METAL BAND ONLY)

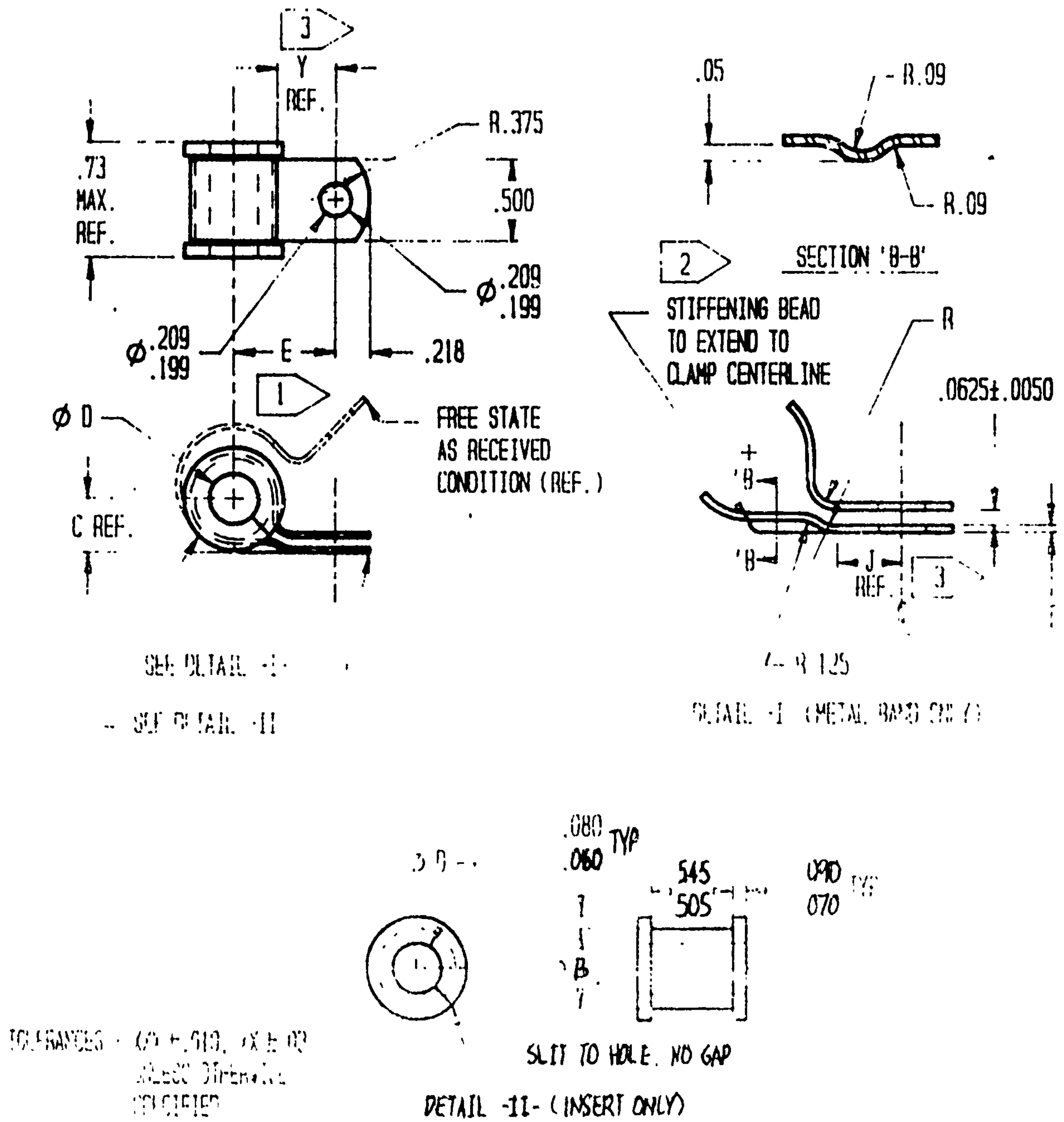


DETAIL II (INSERT ONLY)

MILITARY SPECIFICATION SHEET

CLAMP, INSERT, LOOP, TUBE, 17-7PH CRES., 500° F

THE COMPLETE REQUIREMENTS FOR ACQUIRING THE CLAMPS DESCRIBED HEREIN SHALL CONSIST OF THIS DOCUMENT AND THE LATEST ISSUE IN EFFECT OF SPECIFICATION MIL-C-85052.



MIL-C-85052/1 PROPOSAL

TABLE I

DASH NUMBER	B Ø	C (REF.)	D Ø	E ±.032 [1]	J (REF.) [3]	R ±.010	T	Y (REF.) [3]
1			.062					
2	.375	.25	.125	.593				
3			.188		.235	.090	.020	.325
4			.250					
5	.500	.31	.312	.655				

NOTES

1. DIMENSION 'E' SHALL BE MEASURED WITH THE CLAMP INSTALLED ON A MANDREL OF 'D' DIA. ±.001 AND A .0625± .0005 SPACER BETWEEN THE UPPER AND LOWER FOOT AS SHOWN.

2. STIFFENING BEAD REQUIRED ON ALL SIZES. ALL RADII ON THE STIFFENING BEAD SHALL BE SMOOTH AND BLENDED. NO SHARP TOOL MARKES ARE ALLOWED.

3. REFERENCE DIMENSIONS 'Y' AND 'J' ARE PROVIDED TO GAIN MAXIMUM SUPPORT FOR THE LOWER FOOT BY CLOSELY FITTING THE UPPER FOOT BEND RADIUS TO THE STIFFENING BEAD BLENDED RADII WHEN CLOSED AGAINST EACH OTHER.

4. UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.

5. METAL BANDS SHALL HAVE ALL BURRS, SHARP EDGES AND SCALE REMOVED.

REQUIREMENTS

MARKING : BAND - THE COMPLETE STANDARD PART NUMBER AND MANUFACTURER'S NAME, TRADEMARK, OR FSCM NUMBER SHALL BE IMPRESSION STAMPED ON THE METAL BAND ABOVE THE THEORETICAL CENTERLINE.

INSERT - NONE

MATERIALS : BAND - 17-7PH, CORROSION RESISTANT STEEL PER MIL-S-25043, ANNEALED, STRESS RELIEVED AND HEAT TREATED TO TH1100 CONDITION PER MIL-H-6875 AFTER FORMING.

INSERT - SILICONE RUBBER, UNREINFORCED, [illegible] DUROMETER, COLOR LIGHT BLUE PER THE GENERAL SPECIFICATION WITH ADDITIONAL REQUIREMENTS SHOWN ON THIS SPECIFICATION SHEET

FINISH : BAND - PASSIVATE PER QQ-P-35

INSERT - NONE

MIL-C-85052/7 PROPOSAL

PART NUMBER : PART NUMBER SHALL CONSIST OF THE FOLLOWING (IN SEQUENCE)

1. THE LETTER "M"
2. THE GENERAL SPECIFICATION NUMBER
3. A SLASH, AND SLASH NUMBER OF THIS SPECIFICATION SHEET
4. A DASH, AND THE APPROPRIATE SIZE DASH NUMBER FROM TABLE I

EXAMPLE : M85052/7-1

CUSHION REQUIREMENTS : 1. PHYSICAL PROPERTIES - AS SPECIFIED IN TABLE II. UNLESS OTHERWISE SPECIFIED RESULTS ARE AN AVERAGE OF 5 SPECIMENS AND TOLERANCE ON TEMPERATURE IS (± 5° F).

TABLE II

TEST	TEST METHOD	REQUIRED ORIGINAL PROPERTIES	ALLOWABLE CHANGE FROM ACTUAL ORIGINAL PROPERTIES AFTER :		
			HEAT AGING 70 HRS. AT + 500° F	OIL IMMERSION IN MIL-L-7808 70 HRS. AT + 302° F	DIP TEST *
HARDNESS, DUROMETER "A"	ASTM D2240	65 - 75	+ 10 PTS. MAX.	- 30 PTS. MAX.	+ 5 PTS.
TENSILE STRENGTH - PSI	ASTM D412	1200 MIN.	1000 MIN.	300 MIN.	800 MIN.
ELONGATION - %	ASTM D412	30 MIN.	30 MIN.	30 MIN.	30 MIN.
TEAR STRENGTH - PPI	ASTM D624 (DIE "B")	300 MIN.	300 MIN.	300 MIN.	300 MIN.
VOLUME CHANGE - %	ASTM D471	——	——	+ 45 % MAX.	+ 5 % MAX.
WEIGHT CHANGE - %	ASTM D471	REPORT	- 52 MAX.	——	——
SPECIFIC GRAVITY	ASTM D471	REPORT	——	——	——

* DIP TEST - TEST SAMPLE SHALL BE DIPPED IN A-A-711, TYPE I SOLVENT AND ALLOWED TO DRY AT ROOM TEMPERATURE FOR 24 HRS. THIS PROCEDURE SHALL BE REPEATED 10 TIMES.

2. COMPRESSION SET - SEE MIL-C-85052
   - AIR AGE AT 302° F
   - NOT TO EXCEED 30% AVERAGE OF 3 SPECIMENS

3. FLAMMABILITY - SEE MIL-C-85052
   - SPECIMENS: STANDARD ASTM TEST SLABS
   - VERTICAL BURN TEST

INTENDED USE

THESE CLAMPS ARE INTENDED FOR USE AS FOLLOWS :

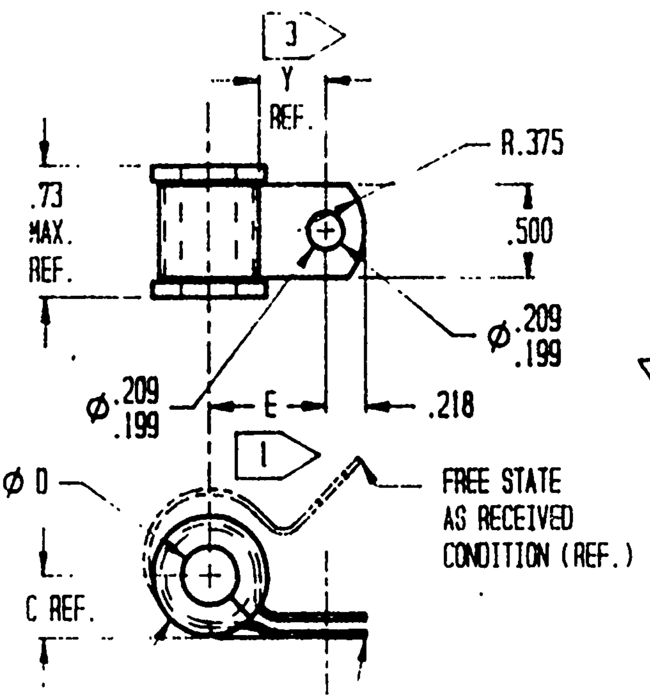
TEMPERATURE RANGE - -65° F TO + 500° F. THESE CLAMPS HAVE CUSHION INSERTS WHICH HAS BEEN COMPOUNDED FOR HIGH TEMPERATURE CAPABILITY AT THE SACRIFICE OF FLUID RESISTANCE, AND IS RECOMMENDED ONLY IN THOSE AREAS WITH OPERATING TEMPERATURES FROM 275° F TO 500° F. [illegible] OF CLAMPS WITH A HIGHER DEGREE OF FLUID RESISTANCE IS RECOMMENDED, SUCH AS MIL C 85052/5 OR MIL C 85052/6

SYSTEMS . ALL FLUID AND ELECTRICAL SYSTEM APPLICATIONS IN HIGH TEMPERATURE AREAS.

MILITARY SPECIFICATION SHEET

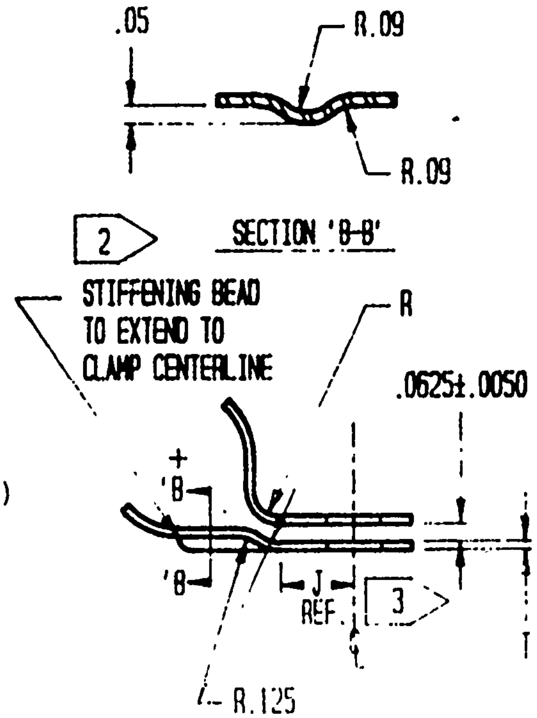
CLAMP, INSERT, LOOP, TUBE, 17-7PH CRES., 500° F

THE COMPLETE REQUIREMENTS FOR ACQUIRING THE CLAMPS DESCRIBED HEREIN SHALL CONSIST OF THIS DOCUMENT AND THE LATEST ISSUE IN EFFECT OF SPECIFICATION MIL-C-85052.

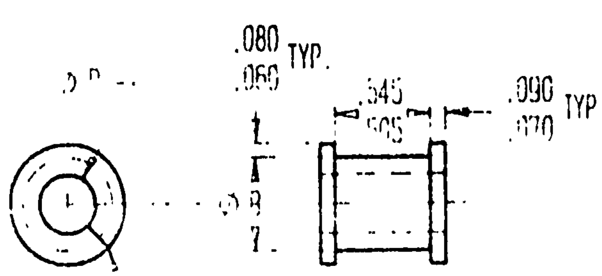


SEE DETAIL -I-

SEE DETAIL -II-



DETAIL -I- (METAL BAND ONLY)



TOLERANCES .XX ±.010 .X ±.03
UNLESS OTHERWISE
SPECIFIED

SLIT TO HOLE, NO GAP

DETAIL -II- (INSERT ONLY)

MIL-C-85052/7 PROPOSAL

TABLE I

DASH NUMBER	B Ø	C (REF.)	D Ø	E ± .032 [1]	J (REF.) [3]	R ± .010	T	Y (REF.) [3]
1			.062					
2	.375	.25	.125	.593				
3			.188		.235	.090	.020	.325
4	.500	.31	.250	.655				
5			.312					

NOTES

[1] DIMENSION 'E' SHALL BE MEASURED WITH THE CLAMP INSTALLED ON A MANDREL OF 'D' DIA. ±.001 AND A .0625± .0005 SPACER BETWEEN THE UPPER AND LOWER FOOT AS SHOWN.

[2] STIFFENING BEAD REQUIRED ON ALL SIZES. ALL RADII ON THE STIFFENING BEAD SHALL BE SMOOTH AND BLENDED. NO SHARP TOOL MARKES ARE ALLOWED.

[3] REFERENCE DIMENSIONS 'Y' AND 'J' ARE PROVIDED TO GAIN MAXIMUM SUPPORT FOR THE LOWER FOOT BY CLOSELY FITTING THE UPPER FOOT BEND RADIUS TO THE STIFFENING BEAD BLENDED RADII WHEN CLOSED AGAINST EACH OTHER.

4 UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES.

5 METAL BANDS SHALL HAVE ALL BURRS, SHARP EDGES AND SCALE REMOVED.

REQUIREMENTS

MARKING : BAND - THE COMPLETE STANDARD PART NUMBER AND MANUFACTURER'S NAME, TRADEMARK, OR FSCM NUMBER SHALL BE IMPRESSION STAMPED ON THE METAL BAND ABOVE THE THEORETICAL CENTERLINE.

INSERT - NONE

MATERIALS : BAND - 17-7PH, CORROSION RESISTANT STEEL PER MIL-S-25043, ANNEALED, STRESS RELIEVED AND HEAT TREATED TO TH1100 CONDITION PER MIL-H-6875 AFTER FORMING.

INSERT - SILICONE RUBBER, UNREINFORCED, 65-75 DUROMETER, COLOR LIGHT BLUE PER THE GENERAL SPECIFICATION WITH ADDITIONAL REQUIREMENTS SHOWN ON THIS SPECIFICATION SHEET.

FINISH : BAND - PASSIVATE PER QQ-P-35

INSERT - NONE

MIL-C-85052/7 PROPOSAL

PART NUMBER : PART NUMBER SHALL CONSIST OF THE FOLLOWING (IN SEQUENCE)

1. THE LETTER "M"
2. THE GENERAL SPECIFICATION NUMBER
3. A SLASH, AND SLASH NUMBER OF THIS SPECIFICATION SHEET
4. A DASH, AND THE APPROPRIATE SIZE DASH NUMBER FROM TABLE I

EXAMPLE ; M85052/7-1

CUSHION REQUIREMENTS : 1. PHYSICAL PROPERTIES - AS SPECIFIED IN TABLE II. UNLESS OTHERWISE SPECIFIED RESULTS ARE AN AVERAGE OF 5 SPECIMENS AND TOLERANCE ON TEMPERATURE IS (± 5° F).

TABLE II

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HARDNESS, DUROMETER "A"	ASTM D2240	65 - 75	+ 10 PTS. MAX.	- 30 PTS. MAX.	+ 5 PTS.
TENSILE STRENGTH - PSI	ASTM D412	1200 MIN.	1000 MIN.	300 MIN.	800 MIN.
ELONGATION - %	ASTM D412	30 MIN.	30 MIN.	30 MIN.	30 MIN.
TEAR STRENGTH - PPI	ASTM D624 (DIE "B")	300 MIN.	300 MIN.	300 MIN.	300 MIN.
VOLUME CHANGE - %	ASTM D471	—	—	+ 45 % MAX.	+ 5 % MAX.
WEIGHT CHANGE - %	ASTM D471	REPORT	- 5% MAX.	—	—
SPECIFIC GRAVITY	ASTM D471	REPORT	—	—	—

* DIP TEST - TEST SAMPLE SHALL BE DIPPED IN A-A-711, TYPE I SOLVENT AND ALLOWED TO DRY AT ROOM TEMPERATURE FOR 24 HRS. THIS PROCEDURE SHALL BE REPEATED 10 TIMES.

2. COMPRESSION SET - SEE MIL-C-85052
   - AIR AGE AT 302 F
   - NOT TO EXCEED 30% AVERAGE OF 3 SPECIMENS

3. FLAMMABILITY - SEE MIL-C-85052
   - SPECIMENS: STANDARD ASTM TEST SLABS
   - VERTICAL BURN TEST

INTENDED USE

THESE CLAMPS ARE INTENDED FOR USE AS FOLLOWS :

TEMPERATURE RANGE : -65° F TO + 500° F. THESE CLAMPS HAVE CUSHION (INSERT) WHICH HAS BEEN COMPOUNDED FOR HIGH TEMPERATURE CAPABILITY AT THE SACRIFICE OF FLUID RESISTANCE. USE IS RECOMMENDED ONLY IN THOSE AREAS WITH OPERATING TEMPERATURES FROM 275° F TO 500° F, WHEN FLUID EXPOSURE IS MINIMAL. FOR APPLICATION BELOW 275° F, THE USE OF CLAMPS WITH A HIGHER DEGREE OF FLUID RESISTANCE IS RECOMMENDED, SUCH AS MIL-C-85052/5 OR MIL-C-85052/6.

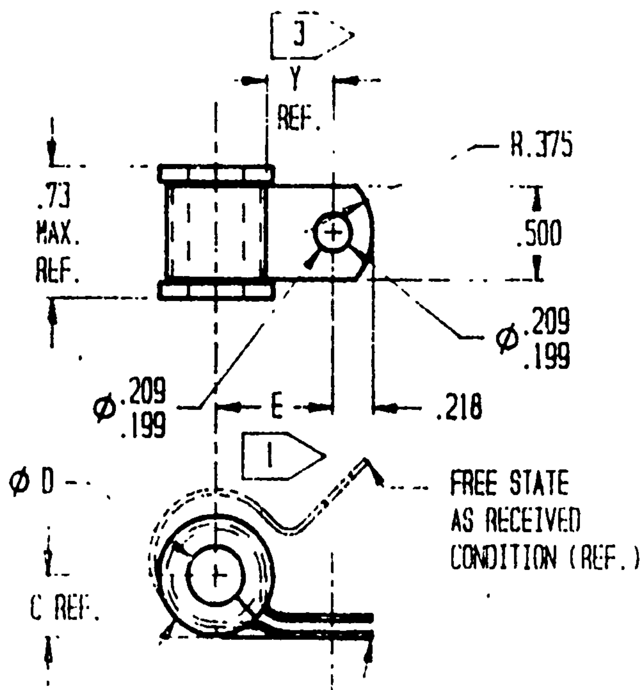
SYSTEMS . ALL FLUID AND ELECTRICAL SYSTEM APPLICATIONS IN HIGH TEMPERATURE AREAS.

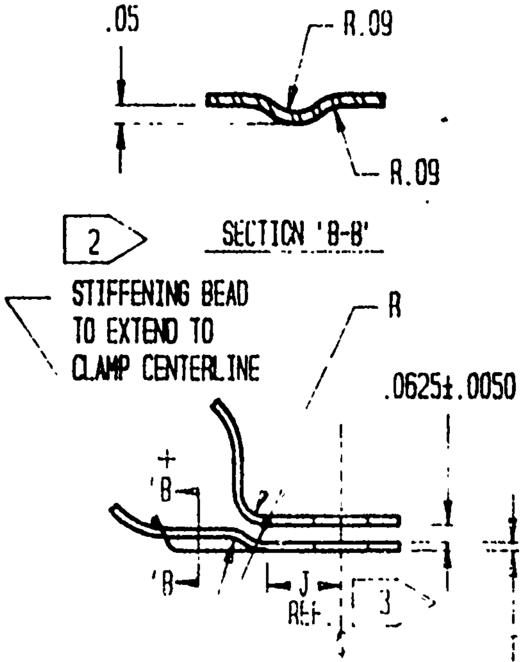
MIL-C-85052/7
PROPOSAL

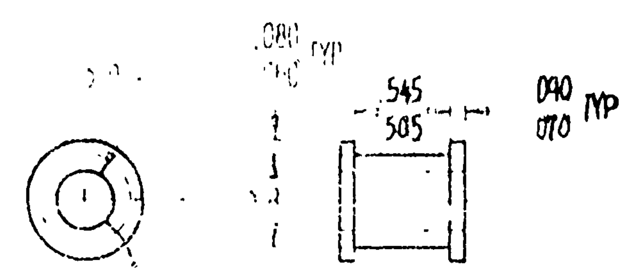
MILITARY SPECIFICATION SHEET

CLAMP, INSERT, LOOP, TUBE, 17-7PH CRES., 500° F

THE COMPLETE REQUIREMENTS FOR ACQUIRING THE CLAMPS DESCRIBED HEREIN SHALL CONSIST OF THIS DOCUMENT AND THE LATEST ISSUE IN EFFECT OF SPECIFICATION MIL-C-85052.







UNLESS OTHERWISE
SPECIFIED

DETAIL -II- (INSERT ONLY)

TABLE I

DASH NUMBER	B Ø	C (REF.)	D Ø	E ± .032 [1]	J (REF.) [3]	R ± .010	T	Y (REF.) [3]
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REQUIREMENTS

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INSERT - NONE

MATERIALS: BAND - 17-7PH, CORROSION RESISTANT STEEL PER MIL-S-[illegible], ANNEALED, STRESS RELIEVED AND HEAT TREATED TO TH1050 CONDITION PER MIL-H-6875 AFTER FORMING

[illegible]

FINISH: BAND - PASSIVATE PER [illegible]

INSERT NONE

MIL-C-85052/7 PROPOSAL

PART NUMBER : PART NUMBER SHALL CONSIST OF THE FOLLOWING (IN SEQUENCE)

1. THE LETTER 'M'
2. THE GENERAL SPECIFICATION NUMBER
3. A SLASH, AND SLASH NUMBER OF THIS SPECIFICATION SHEET
4. A DASH, AND THE APPROPRIATE SIZE DASH NUMBER FROM TABLE I

EXAMPLE : M85052/7-1

CUSHION REQUIREMENTS : 1. PHYSICAL PROPERTIES - AS SPECIFIED IN TABLE II. UNLESS OTHERWISE SPECIFIED RESULTS ARE AN AVERAGE OF 5 SPECIMENS AND TOLERANCE ON TEMPERATURE IS (± 5° F).

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HARDNESS, DUROMETER 'A'	ASTM D2240	65 - 75	+ 10 PTS. MAX.	- 30 PTS. MAX.	+ 5 PTS.
TENSILE STRENGTH - PSI	ASTM D412	1200 MIN.	1000 MIN.	300 MIN.	800 MIN.
ELONGATION - %	ASTM D412	30 MIN.	30 MIN.	30 MIN.	30 MIN.
TEAR STRENGTH - PPI	ASTM D624 (DIE 'B')	300 MIN.	300 MIN.	300 MIN.	300 MIN.
VOLUME CHANGE - %	ASTM D471	-----	-----	+ 45 % MAX.	+ 5 % MAX.
WEIGHT CHANGE - %	ASTM D471	REPORT	- 52 MAX.	-----	-----
SPECIFIC GRAVITY	ASTM D471	REPORT	-----	-----	-----

* DIP TEST - TEST SAMPLE SHALL BE DIPPED IN A-A-711, TYPE I SOLVENT AND ALLOWED TO DRY AT ROOM TEMPERATURE FOR 24 HRS. THIS PROCEDURE SHALL BE REPEATED 10 TIMES.

2. COMPRESSION SET - SEE MIL-C-85052
   - AIR AGE AT 302 F
   - NOT TO EXCEED 30% AVERAGE OF 3 SPECIMENS

3. FLAMMABILITY - SEE MIL-C-85052
   - SPECIMENS: STANDARD ASTM TEST SLABS
   - VERTICAL BURN TEST

INTENDED USE

THESE CLAMPS ARE INTENDED FOR USE AS FOLLOWS :

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SYSTEMS : ALL [illegible] AND ELECTRICAL SYSTEM [illegible] TEMPERATURE AREA

APPENDIX E

SUPPLIER FAILURE ANALYSIS REPORT

FAILURE ANALYSIS REPORT
ON
TITEFLEX METAL HOSE ASSEMBLIES

Titeflex Part Nos.
~~380404003-019~~ 38404003-019
~~380404006-028~~R 38404006-028R
~~380404014-051R~~ 38404014-051R
H. Palm., TITEFLEX

90-TTR-016
DECEMBER 1990

Titeflex Corporation
A Member of the TI Group
Springfield, Massachusetts

TABLE OF CONTENTS

ADMINISTRATIVE DATA

Customer

Rockwell International, Columbus, Ohio

Product

Titeflex 380 Series Metal Braided Teflon Hose

Fittings

Straight to Straight Dual/Seal

Part Numbers

380404003-019, 380404006-028R, 380404014-051R

Assembly Date

June 1989

CUSTOMER FAILURE INFORMATION

Failure of the subject hose assemblies occurred during testing on the customer's high pressure hydraulic distribution test system rig for 8000 psi service. The returned hoses, one (1) -3 with swaged titanium end fittings, one (1) -4 with -5 swaged titanium end fittings, and two (2) -14 with swaged -15 end fittings, were part of a set of 14 hose assemblies submitted to Rockwell in 1989 (see Appendix I).

All hose assemblies were subjected to the same test regimen by Rockwell. This test effort is outlined in Appendix II. The returned hose assemblies leaked at an undetermined point in the test program while the remaining hose assemblies successfully completed the test program.

PRESSURE TESTING

The subject hose assemblies were hydrostatically tested at Titeflex in order to substantiate the leakage condition. Both ends of the -3 hose began to leak at the hose/collar junction at approximately 4000 psi. The -4 hose assembly began to leak at the hose/collar junction of end A at 3000 psi and at 4000 psi at the same relative position on end B. The leakage locations are presented in Plate 1 (Appendix III). The -14 hose assembly began to leak on end A at approximately 50 psi. As with the other assemblies, the leakage occurred at the hose/collar junction and is shown in Plate 2 (Appendix III). The second -14 hose assembly had one fitting separated from the hose when received and was unable to be tested.

PHYSICAL EXAMINATION

The subject hoses were inspected in order to determine the outside, inside, and wire diameters in addition to the number of wires per plait and the number of plaits per inch. No discrepancies were found. The maximum/minimum collar swage diameters were measured and are tabulated below.

Hose Assembly	-3	-4	-14
End A	.478/.474	.5706/.5688	1.430/1.4015
End B	.478/.473	.5715/.5678	1.446/1.428
Per Dwg	.460	.560	1.415

OBSERVATION OF DISASSEMBLED LEAKING FITTINGS

The collars of the subject hose assemblies were split, and the outer braid and intermediate wraps were removed in order to reveal the inner braid. Plate 3 (Appendix III) depicts the condition of the inner braid on the -3 hose in the insert region. The braid was broken in the vicinity of the braidlock at the termination of the TFE innercore. Also present were numerous wire crossovers. There was also evidence of brinelling of the wires laying perpendicular to the adjacent wrap layer.

The condition of the inner braid of the -4 hose assembly is presented in Plate 4 (Appendix III). The photos document a braid crossover located 1.83 inches from the back face of the insert nut of end B. The presence of the crossover resulted in the tensile failure of the adjacent overlaying braid. The spacing of the overlaying wrap, as evidenced by the indentations, resulted in the penetration of the braid into the wrap layer region.

The braid crossovers noted in the -3 and -4 hose were also noted in the -14 hose assembly. The top two photos of Plate 5 (Appendix III) show the condition of end A in the vicinity of the braidlock. These photos also show evidence of extrusion of the TFE innercore. Note that the spacing of the adjacent wrap layer is irregular. In the vicinity of the extrusion, the spacing of the adjacent wrap is in excess of two wrap wire diameters.

The inner braid of each of the subject hose assemblies was removed in order to examine the innercore. Plate 6 (Appendix III) shows the condition of the -3 innercore in the insert region of end B. Inspection of the innercore revealed a hole approximately equal to one wire diameter located .833 inches from the rear face of the nut. The inside diameter of the innercore was inspected to reveal numerous cracks through the conductive layer. These cracks were also noted on end A of the innercore but no holes were detected. This region of the innercore was pressure tested using helium to 400 psig, resulting in the detection of leakage approximately .38 inches from the back face of the insert nut.

Another innercore hole, of approximately one wire diameter, was found on end A of the -4 hose approximately .38 inches from the back face of the nut (see Plate 7, Appendix III). The inspection of the conductive layer of this side of the innercore revealed a longitudinal scratch located approximately 180° from the detected hole. No abnormalities were discovered on end A of the subject innercore. Pressure testing of this end of the innercore was not conducted since this side of the innercore had been previously split for inspection.

The lower portion of Plate 5 (Appendix III) shows the presence of a hole in the -14 innercore located approximately .88 inches from the back face of the insert nut. As in the case of the -3 and -4 innercores, the hole was about one wire diameter in size. The inspection also revealed extensive cracking in the innercore insert region.

CONCLUSIONS

The control of the braid and wrap processes are critical to the performance of ultra high pressure hose assemblies, particularly when subjected to elevated temperatures. This is especially true in the insert region where the wires must undergo additional pressure due to the compressive load placed upon the wire by the collar. The inner braid of the subject hose assemblies showed a large number of wire crossovers. On the -4 and -14 hose assemblies, the evidence indicates that spacing existed on the adjacent layer of wrapping. These conditions produce local variations in both the wall thickness and stiffness of the hose resulting in tensile failure of the wire and both extrusion and cracking of the innercore in the insert region during collar swaging. In the presence of pressure and thermal cycling, the structural deficiencies described above conspire to create innercore leakage paths when a broken wire cuts into the innercore in the vicinity of a crack.

The samples submitted to Rockwell International were fabricated on a best effort basis. Hose assemblies submitted in this manner were only proof pressure tested in order to detect infant failures. The three subject hose assemblies represent 21% of the total number of hose assemblies submitted to Rockwell for test. The remaining hose assemblies successfully completed the Rockwell test regimen.

RECOMMENDATIONS

The braiding and wrapping process must be more tightly controlled in order to significantly reduce or eliminate the presence of crossovers and gaps within the wire wrap construction. Titeflex is evaluating methods for better wrapping and automatic inspection for wrapping reinforcement of 8000 psi hydraulic hoses.

Written By: ______________________
Walter S. Nuhfer
Sr. Project Engineer

Approved By: ______________________
J. M. Lalikos
Vice President, Engineering

APPENDIX I

Hoses Submitted for Test

HOSE ASSEMBLIES SUBMITTED TO ROCKWELL FOR TEST				
Assembly No.	Titanium Fittings	No. Submitted	Test Date	No. of Failures
38404003-019U		2	7/14	1
38404004-028R	-5	2	6/2	1
38404006-028R	-7	2	6/16	
38404008-0315R	-9	2	6/16	
38404010-0365R	-11	2	6/16	
38404012-042R	-13	2	6/2	
38404014-051R	-15	2	6/2	2
Total Assemblies Submitted 14				

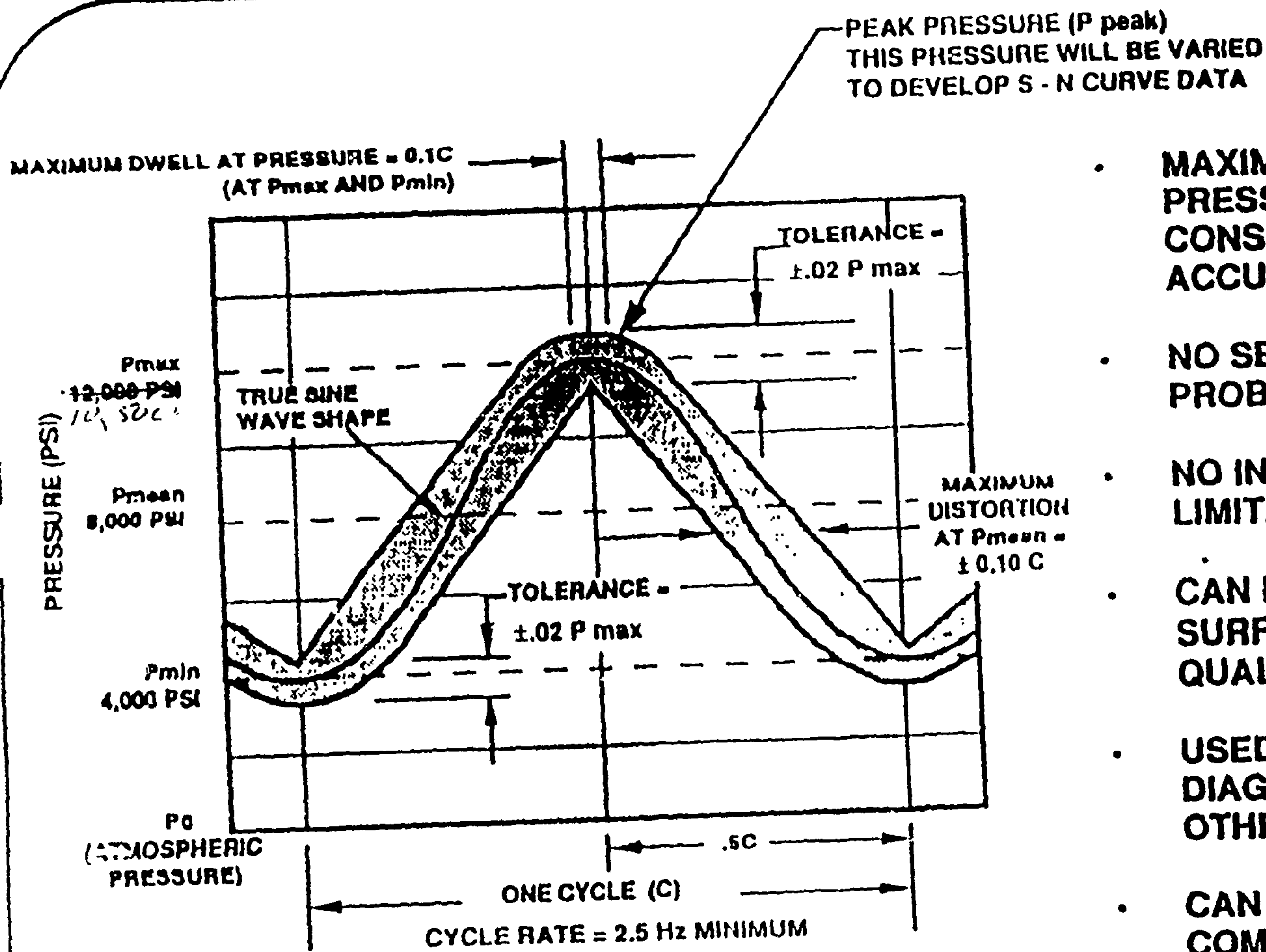
90-77R-016

APPENDIX II

Rockwell Test Program Outline

ADVANTAGES OF SINE WAVE IMPULSE TESTING

HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM



P min =.02 P max

P mean =.5 (P max - P min)

- MAXIMUM AND MINIMUM PRESSURES ARE HELD CONSISTENTLY AND ACCURATELY RECORDED
- NO SECONDARY WAVE EFFECT PROBLEMS
- NO INHERENT PRESSURE PEAK LIMITATIONS
- CAN DISCRIMINATE BETWEEN SURFACE FINISHES, BEND QUALITY EFFECTS, ETC.
- USED WITH CONSTANT LIFE DIAGRAM AND EXTRAPOLATE TO OTHER OPERATING CONDITIONS
- CAN BE USED ON ANY COMPONENT CONFIGURATION

ROCKWELL INTERNATIONAL CORPORATION

PROGRAM REQUIREMENTS

HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM

Hydraulic System Pressure	8000 PSI
Test Fluid	MIL-H-83282
Fluid Temperature Range	-65°F TO 400°F
Tubing Material	Titanium 3AL-2.5V
Tube Sizes	3/16 Through 5/16

ROCKWELL INTERNATIONAL CORPORATION

PHASE III DEMONSTRATOR TESTING

HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM

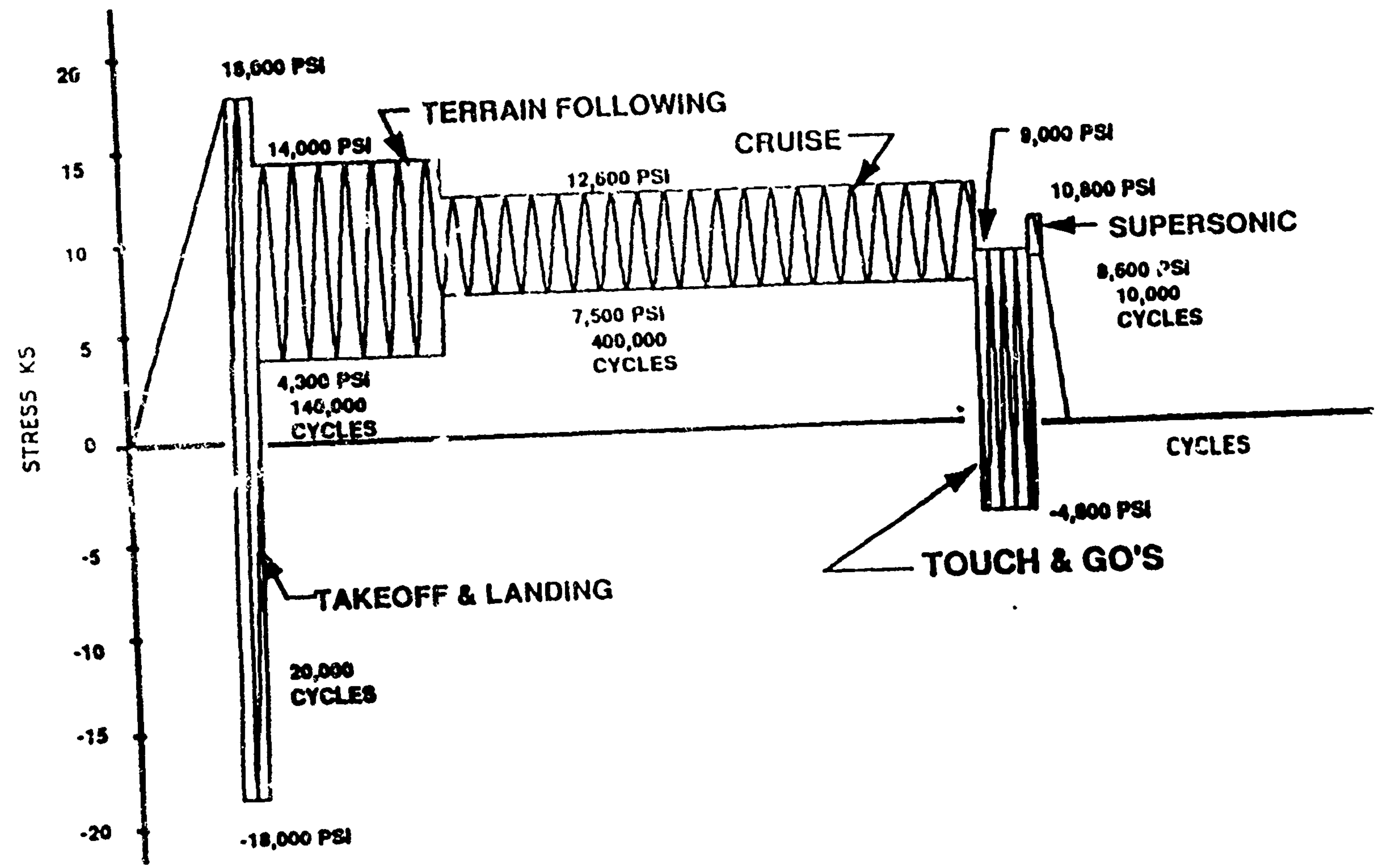
- **Design and fabricate a distribution system demonstrator to subject hydraulic system components to expected advanced A/C environment**

Plumbing Hardware:	Based on best performer during screening tests 50 feet of tubing (3/16 through 5/16) 2 boss fittings 5 detachable fittings 10 permanent fittings Hoses / Swivels / Quick Disconnects
Demonstrator Capabilities:	Structural vibration Structural flexure Pump pressure pulsations System pressure oscillations Thermal environment
Durability test:	2500 flight hours

ROCKWELL INTERNATIONAL CORPORATION

MISSION PROFILE - FLEXURE

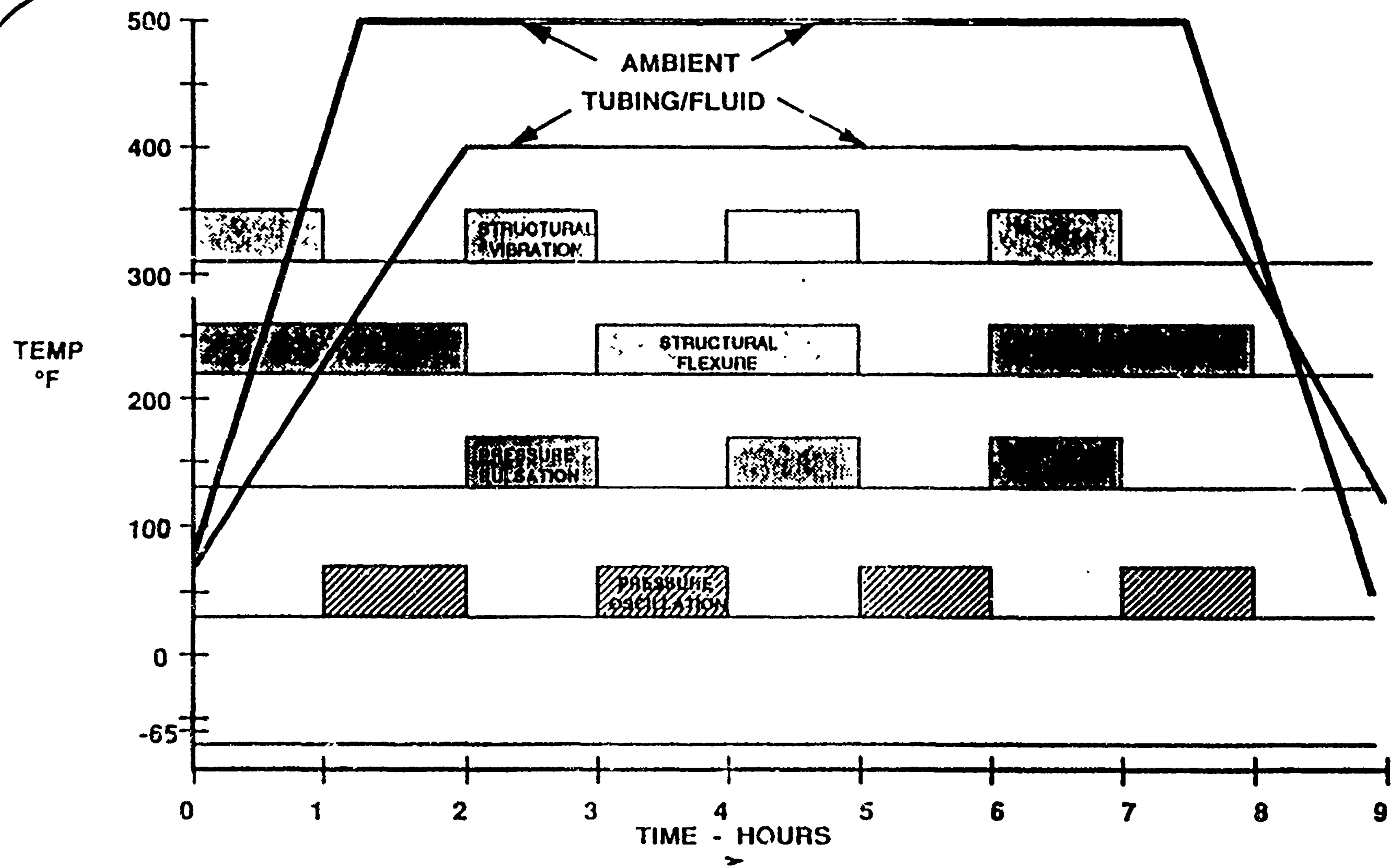
HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM



ROCKWELL INTERNATIONAL CORPORATION

HIGH TEMPERATURE TEST PROFILE

HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM



REPEAT THE ABOVE 8 HOUR TEST - 18 TIMES

TEST SUMMARY

HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM

ITEM	REQUIREMENT	ACTUAL
TEST TIME, Hrs.	125	134.5
MECHANICAL FLEX, Cy	305,000	432,000
HOSE/SWIVEL FLEX, Cy	44,955	44,955
VIBRATION, Cy	86,400,000	132,885,000
THERMAL CYCLES, Cy	18	18
THERMAL GRAD'NT, Cy	2	0
PUMP PULSATIONS, Cy	270,000,000	57,304,800
SINE WAVE IMPULSE, Cy	375,000	18-60,000

TEST SUMMARY - HARDWARE

HIGH PRESSURE HYDRAULIC DISTRIBUTION SYSTEM

- HARDWARE TESTED (210)
  - 14 SWIVELS
  - 14 DISCONNECTS
  - 14 HOSES
  - 74 PERMANENT FITTINGS
  - 94 DETACHABLE FITTINGS

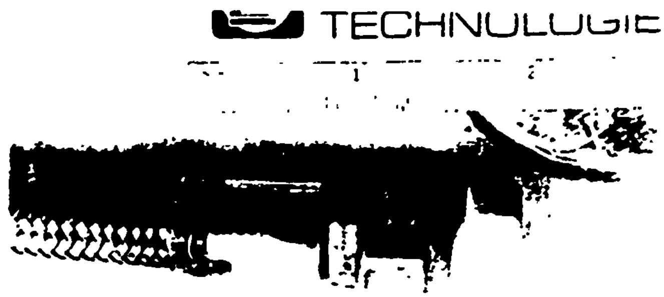
- HARDWARE FAILURES (7)
  - 3 DISCONNECT (SEATON - WILSON)
  - 3 DISCONNECT (SYMETRICS)
  - 3 SWIVEL (KRUGER)
  - 3 HOSES (2) (TITEFLEX (1)
  - 5 HOSE (TITEFLEX)
  - 15 HOSE (TITEFLEX)

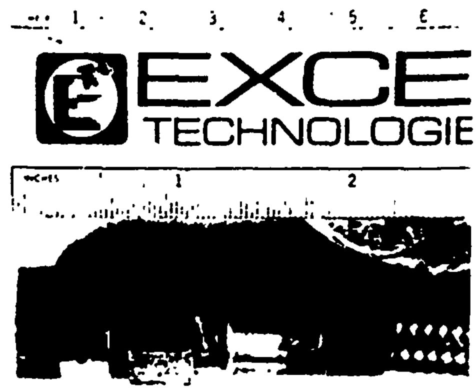
APPENDIX III

Plates 1 - 7

PLATE 1

380 SERIES ROCKWELL HOSE FAILURE
AS RECEIVED FROM ROCKWELL





.473/.474 P/N 38404003-019 COLLAR DIAMETERS .478/.473

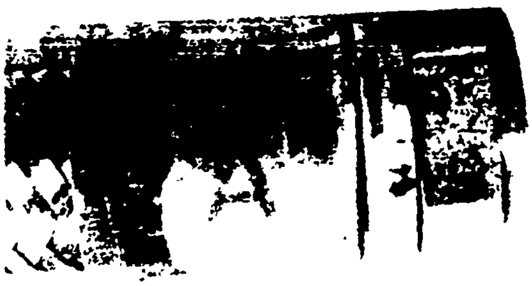
.5706
.5688

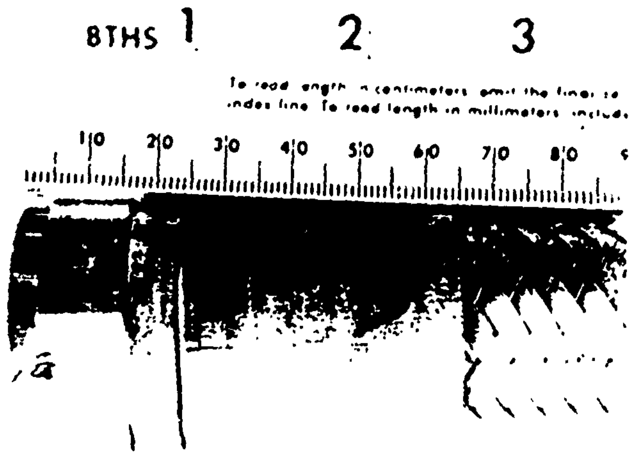
P/N 38404006-028R COLLAR DIAMETERS

.5715
.5678

PLATE 2

380 SERIES ROCKWELL HOSE FAILURE
AS RECEIVED FROM ROCKWELL

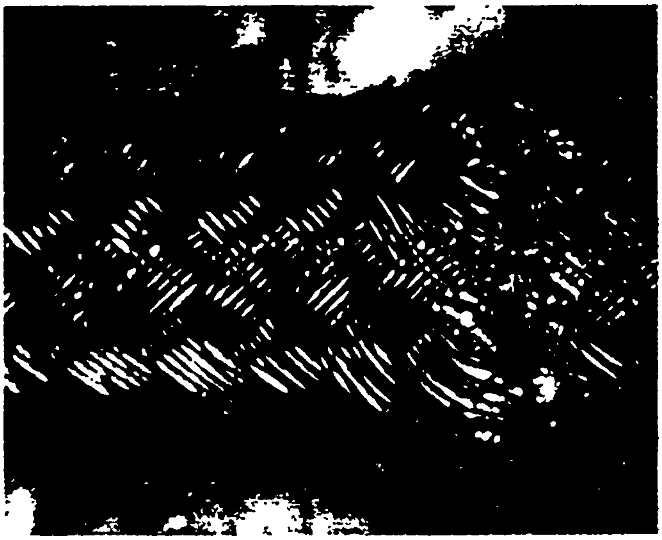


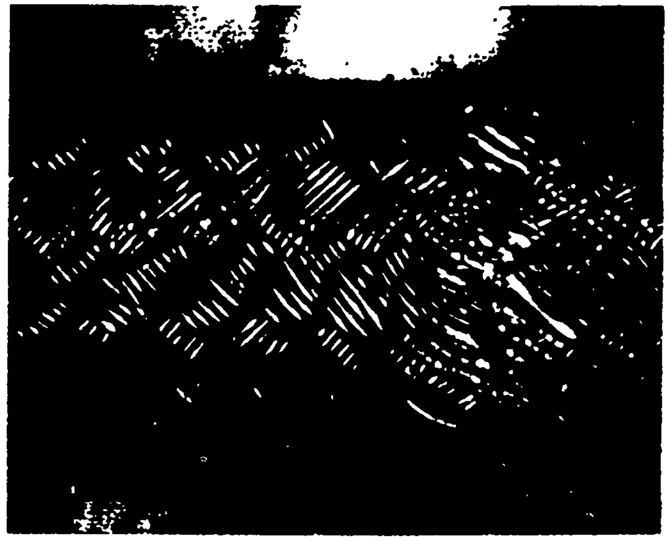


1.430	P/N 38404014-051R COLLAR DIAMETERS	1.446
1.4015		1.428

PLATE 3

380 SERIES ROCKWELL HOSE FAILURE
INNER BRAID CONDITION





P/N 38404003-019 SIDE A

OVERVIEW ABOVE SHOWS BROKEN BRAID IN THE DOGLOCK REGION. CLOSEUP BELOW.

P/N 38404003-019 SIDE B

OVERVIEW ABOVE SHOWS BROKEN BRAID ABOUT 1/2" FROM THE DOGLOCK REGION. CLOSEUP BELOW.

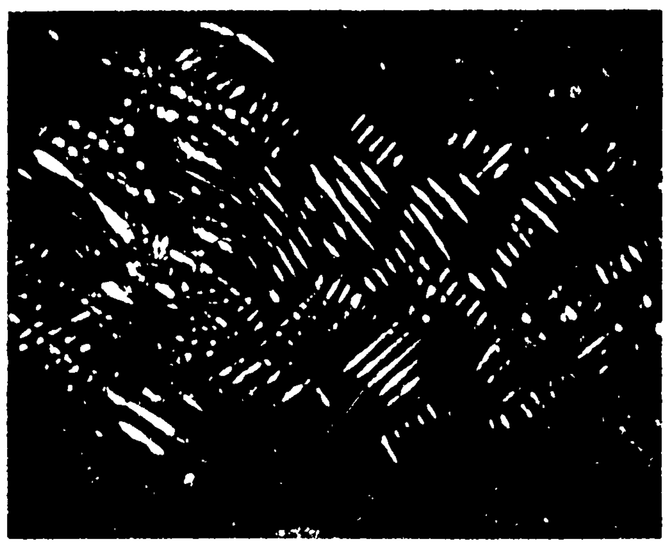
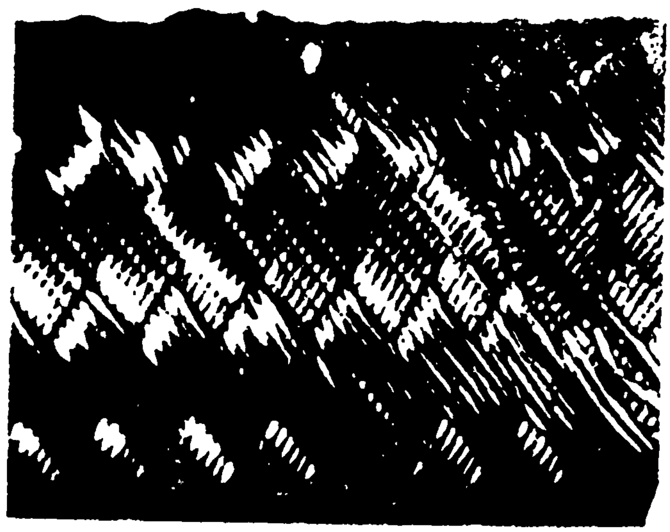


PLATE -

380 SERIES ROCKWELL HOSE FAILURE
INNER BRAID CONDITION

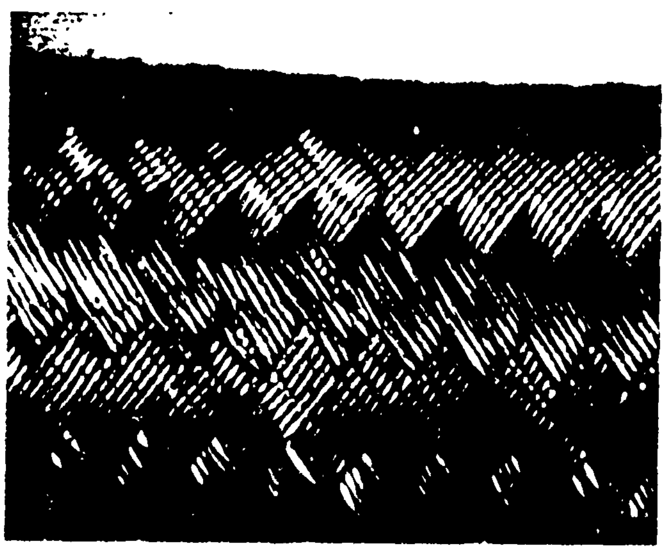
P/N 38404006-028R SIDE B

PROFILE OF BROKEN BRAID 1 5/8"
FROM NUT



P/N 38404006-028R SIDE B

OVERHEAD OF BROKEN BRAID 1 5/8"
FROM NUT

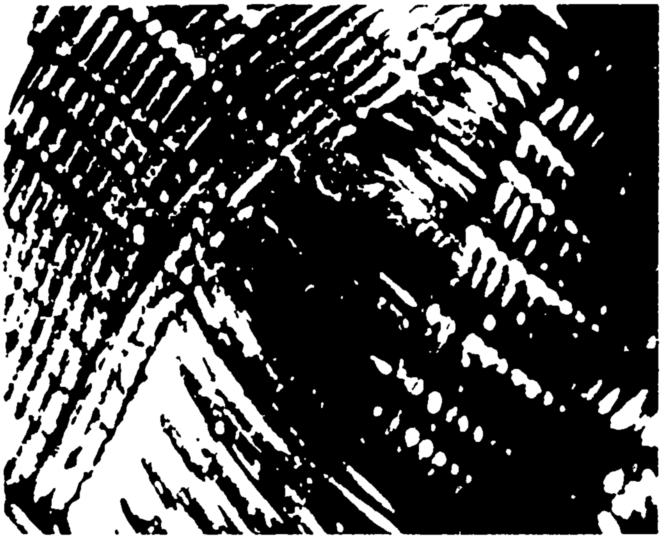


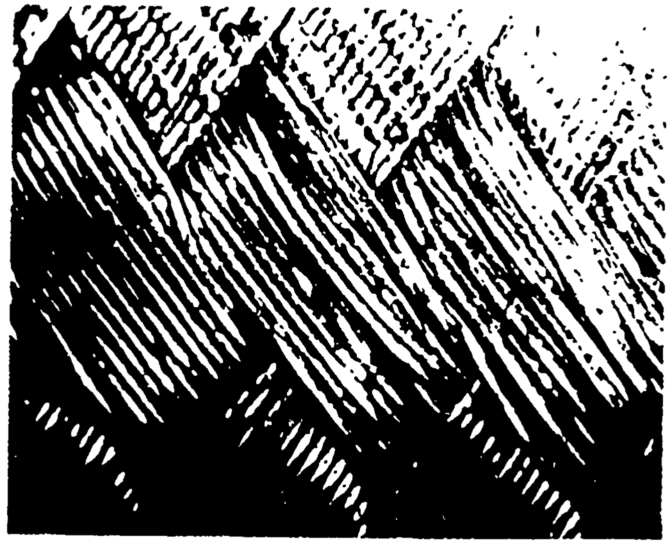
P/N 38404006-028R SIDE A

ABOUT 3/4" FROM NUT

PLATE 5

380 SERIES ROCKWELL HOSE FAILURE
INNER BRAID CONDITION
P/N 38404014-051R



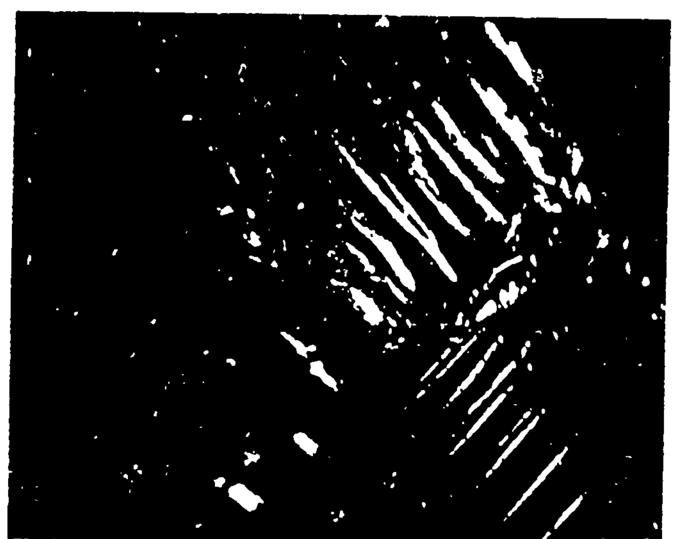


SIDE A

EXTRUDED TEFLON NOTED IN THE VICINITY OF THE NIPPLE TOWARDS THE DOGLOCK END.

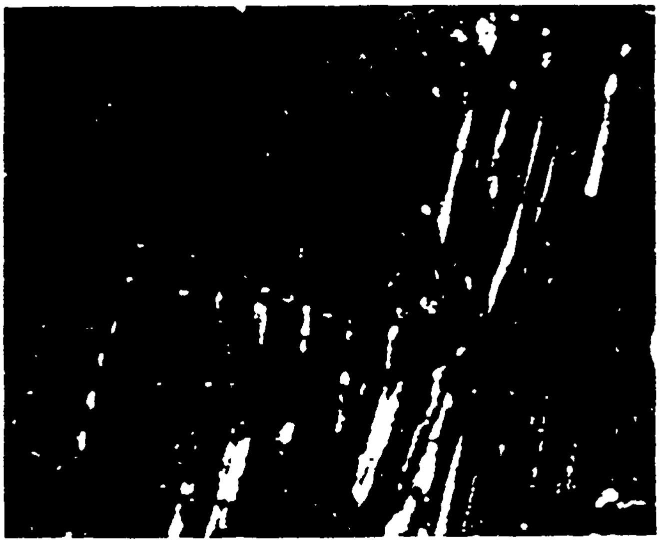
380 SERIES ROCKWELL HOSE FAILURE
EVALUATION OF THE INNERCORE
7/8" FROM INNERCORE END WHERE
HOLE WAS FOUND.
P/N 38404014-051R

15X



20X

PLATE 6
380 SERIES HOSE FAILURE
AS RECEIVED FROM ROCKWELL
LEAK DETECTION OF INNERCORE
P/N 38404003-019 SIDE B



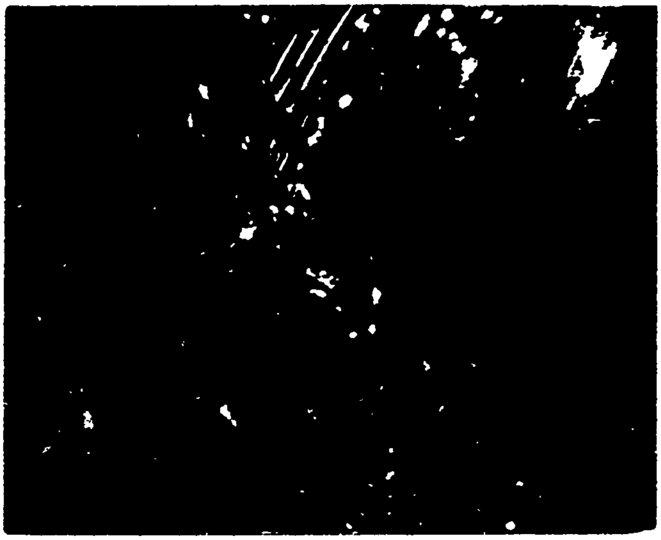
OVERVIEW OF A HOLE LOCATED .833" FROM THE NUT FACE OF THE FITTING.

X-SECTION OF INNERCORE OF THE HOLE SHOWING A FISSURE .833" FROM THE NUT FACE.

INTERIOR VIEW OF THE INNERCORE IN THE VICINITY OF THE FISSURE.

PLATE 7

380 SERIES ROCKWELL HOSE FAILURE
EVALUATION OF INNERCORE
P/N 38404006-028R SIDE A



HOLE OBSERVED IN THE FITTING REGION 3/8" FROM THE END OF THE INNERCORE.

LONGITUDINAL SCRATCH ALONG ENTIRE INSERT REGION OF INNERCORE LOCATED APPROXIMATELY 180° FROM THE HOLE.

SYSTRON DONNER

SEATON-WILSON DIVISION

FAILURE ANALYSIS

DATE 11-5-90

Customer Rockwell - North American Aircraft Operations

P.O. No. -

Orig. Job No. C-1650 (Obtain from S/N files and notify sales desk)

Customer P/N

Revision -

S-W P/N ZFF-52V-3-DTB3 Male ZFF-53V-3-DT3 Female

No. of Failed Parts 1

Part Name Male Disc.

Item No. N/A

Customer Receiving Report No. N/A (Note: Make certain this number appears on invoice at time of reshipment.)

Orig. Lot Size 2

Serial No. 101

S-W Receiving Report No. N/A

Assembly Date 2Q89

CUSTOM DESCRIPTION OF FAILURE

Leakage at male valve.

ENGINEERING INSTRUCTIONS

1. Disassemble.
2. Photograph failed and unfailed parts.
3. Obtain contaminant count.
4. Describe failed part.

RESULTS OF SEATON-WILSON ANALYSIS:

(1) VISUAL, PHYSICAL CONDITION:

Both male and female half show evidence of charred fluid externally and internally. Considerable internal debris is evident.

(2) [X] FAILURE VERIFIED [ ] FAILURE NOT VERIFIED.

(Describe tests performed to verify failure or non-failure)

Male valve leaks. Female does not leak.

(3) CAUSE OF FAILURE

(Note all dimensions and calculations on a second sheet)

A. Large section of male valve o-ring missing (M83461 1).

B. Later found piece in general debris inside male Q.D. Believe that high local temp. in disconnected mode and subsequent movement caused section of o-ring to be torn from o-ring. (See attached photos). Impossible to obtain particle count.

(4) REMEDY

(If extensive, note on a second sheet)

(5) FILL OUT DETAIL R&O INSTR SHEETS FOR ITEMS TO BE REPLACED OR REWORKED

(Forward to Engineering when completed)

SYSTRON DONNER
A THORN EMI company

SEATON-WILSON DIVISION

FOR ENGINEERING USE

(6) RESPONSIBILITY N/A Assy was submitted to cust. for tests. S-W ( ) Customer ( )
(Reason, if not S-W responsibility)

(7) ENGINEERING TO CONTACT CUSTOMER IF CHANGE IN DISPOSITION:

Customer Contact ____________ Date ____________

Agreement Obtained From ____________ Date ____________

(8) CORRECTIVE ACTION TO PREVENT RECURRENCE (IF REQUIRED):

Engineer ____________ Date 11-6-90

FOR ASSEMBLY USE

(9) DISPOSITION

a) If S-W responsibility, send this form, R&O instructions, and parts to Production Control.

Date Forwarded ____________

b) If customer responsibility, make our repair and overhaul analysis and staple to this form.

FOR PRODUCTION CONTROL USE

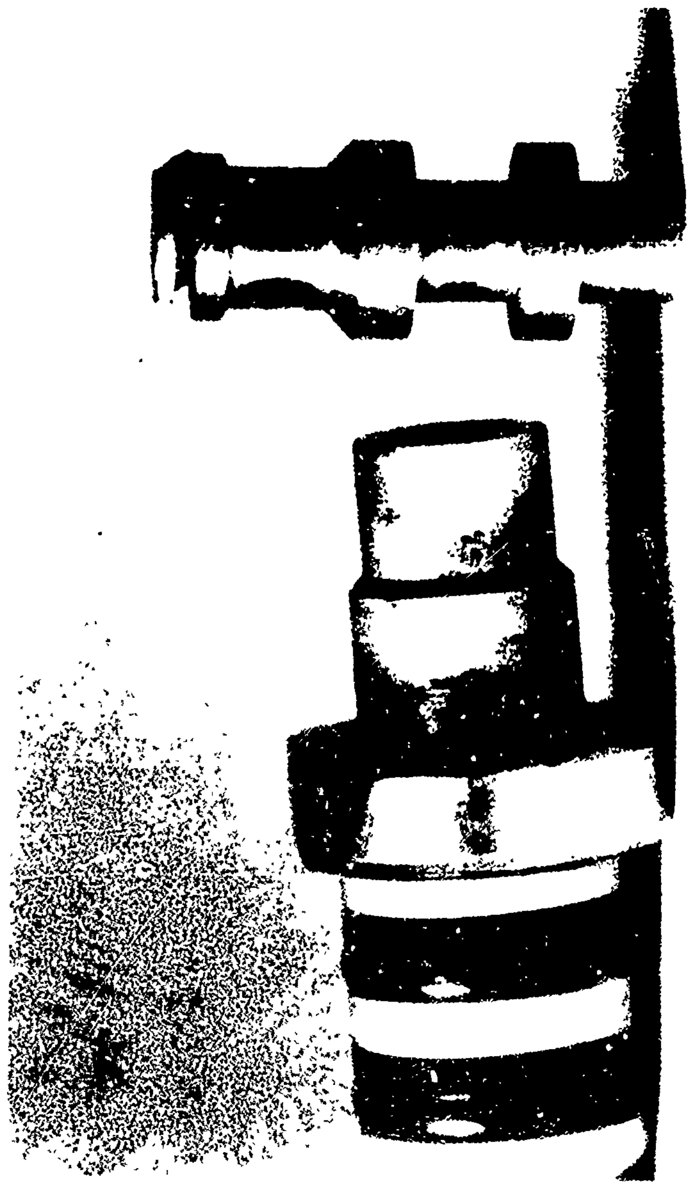
(10) JOB RELEASE Parts & R&O instructions received from Assembly

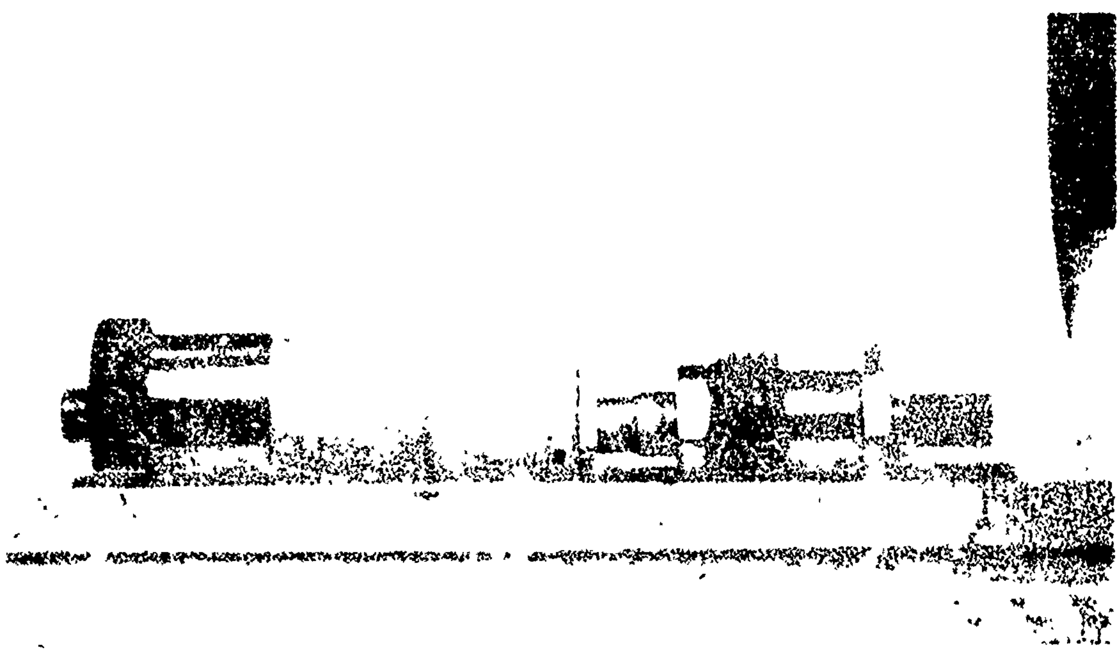
Date ____________ Due Date ____________ (See Below)

a) Are all required parts in stock? Yes ____ No ____

1) If yes, forward all parts and paper work to Assembly Assembly is then to notify Sales of shipment date

2) If no, make prints associated travelers (without dates) and then release to Shop and/or Purchasing Assembly s due date is to be two (2) weeks after the release date which must be entered on the P/L (Only the Sales Department can change this date)





RUBLY ENGINEERING CO. MANUFACTURERS' REPRESENTATIVES

2140 WESTWOOD BOULEVARD, LOS ANGELES, CALIFORNIA 90025 • (213) 474-2503 FAX 213-475-0936

December 19, 1990

North American Aircraft Operations
Rockwell International Corporation
201 North Douglas Street
P.O. Box 92098
Los Angeles, CA 90009

Attention: Msrs. J. Schmidt/D. Blanding

Subject: Rudolph E. Krueger, Inc.
883 West 16th Street
Newport Beach, CA 92663
Ernst Krueger - Tel: 714/646-0136

Reference: 8000 PSI Demonstration Test -
Rudolph E. Krueger, Inc. - Swivels

Gentlemen:

Following is a summary of the results of an analysis of performance related to the Rudolph E. Krueger, Inc. Swivels that were a part of your Air Force Demonstration for 8,000 psi. Hydraulic Systems.

The Swivels in question were -3 Sizes and were found to be:

Swivel Number E-RK-03

Retrieved this Swivel from its shipping box
Hooked up this Swivel to our Hydraulic Pump
Pumped Fluid into the Swivel and bled off the entrapped air
When air bled off, subjected the Swivel to Test Pressure
Found Minor leak (3,000 psi to 1,000 psi in 4 days)
Tore down swivel for inspection and found:

a) Surface marr on sealing surface on nut end
b) One piece of small metal flake (from our machining)
c) Large chunk (1/16 dia.) of hard foreign material (could be from within other systems-transferred to ours)

Refinished seal surface and the leak disappeared.

North American Aircraft Operations
Rockwell International Corporation
Msrs. J. Schmidt/O. Blanding
December 19, 1990
Page 2

Swivel, No Serial Number Markings

Pressure Tested this Swivel and found it to have good pressure integrity (No Leaks).

This represents the summary of our findings with respect to our Swivels provided us upon conclusion of the above referenced tests.

Signed Ernst Krueger

Very truly yours,

RUBLY ENGINEFRING CO.

W. A. Rubly

Wm. A. Rubly

WAR:ehh